DAILY LIGHT INTEGRAL REQUIREMENTS FOR ZOYSIAGRASS AND BERMUDAGRASS CULTIVARS: FERTILITY, MOWING HEIGHT, AND GROWTH REGULATOR INTERACTIONS

A Thesis

by

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ABSTRACT

Growing quality turf in shade is a significant management concern for many turf managers. Proper turfgrass selection for shaded environments can be challenging due to difficulty in quantifying necessary light levels particular to each unique environment. Rather than responding to a number of hours of sunlight or percent shade level, plants ultimately respond to the cumulative daily total number of photons (mols m^{-2} d^{-1}) received within the photosynthetically active wavelengths (400-700 nm), termed 'daily light integral' (DLI). Most prior works investigating turfgrass DLI requirements have been with bermudagrass putting greens and shorter-term greenhouse studies. Furthermore, little to no research has examined Nitrogen (N) rate and trinexapac-ethyl (TE) interactions on the shade tolerance of 'Tifway' bermudagrass under golf or athletic turf situations.

A field study was conducted over multiple seasons under replicated treatments offering 0 to 90% reductions in photosynthetic photon flux (PPF) and investigating effects of mowing heights and monthly TE (0.2 kg ai ha^{-1}) application during summer months. Our results demonstrated that zoysiagrass cultivars achieved superior turf quality, maintained higher levels of green cover and NDVI, higher shear strength measurements, and had overall lower DLI requirements than bermudagrass cultivars under moderate to heavily (50-90% shade) shaded conditions. Monthly TE application and increased mowing heights simulating golf course rough also improved turf quality and performance of all cultivars under low-light conditions. Seasonal differences in DLI

were also noted across cultivars, with highest DLI requirements observed in summer and reduced DLI occurring in spring and fall seasons.

A greenhouse study was then conducted under Full Sun, 30%, and 50% shade levels to evaluate effects of N and TE on Tifway bermudagrass performance over a 12-week period. Results demonstrated that TE (0.1 kg ai ha^{-1} per 14 days) application combined with low N rate (9.96 kg N ha^{-1} per 14 days) benefited shaded Tifway bermudagrass in terms of both turf quality and percent green cover. Also, high N rate (24.4 kg N ha^{-1} per 14 days) with TE application contributed to improved turf quality relative to high N rate without TE application. The high N rate also contributed to greater clipping yields under both full sun and shade environments. These data offer insight to turf managers for improving turfgrass cultivar selection and cultural management for shaded conditions.

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Contributors

This work was supervised by a thesis committee consisting of Professor Benjamin Wherley [advisor], Russell Jessup [co-advisor] and Casey Reynolds of the Department of Soil and Crop Science and Professor Young-Ki Jo of the Department of Plant Pathology and Microbiology.

All work for the dissertation was completed by the student, under the advisement of Professor Benjamin Wherley of the Department of Soil and Crop Science.

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NOMENCLATURE

DLI	Daily Light Integral
NDVI	Normalized Difference Vegetation Index
TE	Trinexapac-ethyl
N	Nitrogen

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

The earliest grasses are thought to have been broad-leaved, rhizomatous, and evolved from primitive forest-dwelling species (Clark et al., 1995). Grasses have undergone comprehensive changes in morphology and physiology to adapt to full sunlight environment. One such change is an altered flower morphology to facilitate wind-aided, rather than insect-aided pollination (Gardner and Goss, 2013). More importantly, grasses have had to develop mechanisms for coping with increased transpirational demand associated with open environments. Today's turfgrasses are therefore much less adapted to the shade environment because they evolved over millions of years to adapt to growth in full sunlight (Gardner and Goss, 2013).

It has been estimated that approximately 1 to 5% of the total solar energy reaching earth is utilized for photosynthesis (Cooper, 1970). Plants utilize sunlight from a distinct region of the electromagnetic spectrum between the wavelengths 400 and 700nm, referred to as photosynthetically active radiation (PAR). The amount of PAR received at a giving location can be quantified through a unit of measure known as photosynthetic photon flux (PPF), commonly measured in units of μmol m^{-2} s^{-1} (Bell et al., 2000; Wherley et al., 2003). For reference, in the midwestern United States, PPF of approximately ~1900 μmol m^{-2} s^{-1} on the earth's surface could be expected for a cloudless day at solar noon. Vegetative, building, or stadiums can have profound effects on solar radiation reaching the turfgrass. Deciduous tree canopies significantly alter both the spectral composition (primarily red to far-red ratio) and PPF of solar radiation available to plants in shade, which significantly affects plant growth and development (Shirley, 1945). Vegetative shade alters both quantity (PPF) and spectral composition of sunlight, whereas stadium or other structural shade sources tend to primarily reduce PPF (Tegg and Lane, 2004).

The minimal light requirement of a plant is closely associated to a plant's light compensation point (LCP). The LCP is defined as the light intensity (level of PPF) at which the rate of photosynthesis equals the rate of respiration (Danneberger, 1993). Therefore, if a plant receives light intensity below that of the LCP for an extended period of time, it will soon begin to deplete available carbohydrate reserves for respiration and die (Wilkinson et al., 1975).

General physiological responses of turf to reduced irradiance include decreases in photosynthesis, respiration rate, carbohydrate reserves, C/N ratio, transpiration rate, and osmotic pressure. Shaded turf plants also exhibit increased water content, chlorophyll, and lignin (Woledge, 1971; Dudeck and Peacock, 1992). Morphological changes occurring in shaded turfgrass tend to include decreases in leaf thickness, leaf width, stem diameter, dry weight, shoot density, and rhizomes and stolon growth. Shaded grasses also exhibit increased root/shoot ratio, greater specific leaf area (leaf area per unit leaf weight), leaf succulence, leaf length, vertical growth habit, and plant height (Woledge, 1971; Dudeck and Peacock, 1992; Kephart et al., 1992). From a morphological perspective, the most apparent response to a low light environment is an increase in the elongation rate of the stem, which is often referred to as the 'shade-avoidance response'.

Vegetation alters spectral composition of sunlight by intercepting primarily the blue (400-500nm) and red (600-700 nm) wavelengths, while transmitting the far-red (700-735 nm). The exclusion of blue light as shade level increases has been considered to be the most critical wavelength missing for turfgrass growth (McBee, 1969). Plant perception of R:FR ratio is also an important aspect of shade acclimation (Holmes and Smith, 1975). Changes in R:FR ratio influence plant development by altering phytochrome equilibrium. Plant responses to decreased R:FR ratio include increased stem elongation, reduced leaf area, reduced branching/tillering, and changes in chlorophyll content (Dudeck and Peacock, 1992).

It has been estimated that 25% of all turfgrass must be managed in some degree of shade (Beard, 1973). Therefore, selecting appropriate species and cultivars as well as application of effective cultural management strategies for managing turfgrass in shaded environments are important aspects of sustainable turf management. Managing turf in shade can be challenging due to difficulty in precisely quantifying light levels particular to each environment as well as lack of data on minimal light requirements of turfgrass species/cultivars. Complexity variability among shade environments make it difficult to specify a minimum light requirement in terms of 'hours per day' or 'percent shade' tolerable by a specific cultivar that can extend across various situations. Biologically speaking, rather the responding to a number of hours of sunlight or percent shade level, plants ultimately respond to the cumulative daily total number of photons (mols m^{-2} d^{-1})

they receive within the photosynthetically active wavelengths (400-700 nm), termed 'daily light integral' (DLI). For reference, in Houston, TX, ambient DLI in full sun fluctuates from as low as ~17 mols m^{-2} d^{-1} during the winter months, to over ~42 mols m^{-2} d^{-1} during the summer (Korczynski et al., 2002).

Minimum DLI levels needed to sustain acceptable quality for a particular cultivar therefore likely do not remain constant across the season, but may vary by season of the year, and could be influenced simultaneously by temperature effects on photosynthetic/respiratory balance. Soil temperature in shade can be an interacting factor contributing to delayed spring green-up, transition issues, and winter injury (Beard, 1973), and this has often been overlooked in previous shade research. Relative humidity levels can also be elevated in shade environments, contributing to extended leaf wetness and higher disease pressure in shaded environments (Beard, 1973).

Cultivars

The majority of past research has tested and reported turf performance in shade in relation to percent or hours of shading. One such study, conducted in Fayetteville, AR included seven zoysiagrass (*Z. japonica* Steud. and *Z. matrella* (L. Merr.) and five bermudagrass (*C. dactylon* (L.) Pers. X *C. transvaalensis* Burt-Davy) cultivars managed under golf course fairway conditions (Trappe et al., 2011). The authors evaluated percent green cover in plots over an 18 months period under two shade levels (full sun and 49% shade). The top-performing entries in the study were found to be 'Cavalier', 'Diamond', 'El Toro', 'Meyer', 'Palisades', and 'Zorro' zoysiagrass, as well as 'Princess 77' and 'Riviera' bermudagrass. Conversely, 'Patriot', 'Tifsport', and 'Tifway' bermudagrass, as well as ‘Zenith’ zoysiagrass were found to be some of the lower-performing entries in the study. Bunnell et al. (2005a) conducted a study which included Celebration, Tifway and TifSport bermudagrass as well as Meyer Japanese zoysiagrass in South Carolina utilizing density neutral shade fabric treatments resulting in shade levels of 0, 40, 58, and 71% shade. The authors noted that Tifway and TifSport maintained acceptable quality until shade levels increased beyond 40%. Also, ‘Celebration’ maintained acceptable turf quality up to shade levels of 58%, while Meyer Japanese zoysiagrass maintained acceptable turf quality up to shade levels of 71%.

An increasing amount of research is now recognizing the importance of DLI in relation to shaded turf performance, however, a limited amount of published turfgrass research exists on the subject. Recently, Meeks et al. (2015) conducted short-term greenhouse experiments to determine DLIs for tall fescue and hybrid bluegrass cultivars genotypes. The authors reported DLIs ranging from as low as 0.8 to 18 $mol \cdot m^{-2} \cdot d^{-1}$for hybrid bluegrass and 8.8 $mol \cdot m^{-2} \cdot d^{-1}$for tall fescue cultivars. Bunnell et al. (2005b) reported a DLI of 32.6 mol m^{-2} d^{-1} for ‘TifEagle’ ultradwarf bermudagrass putting greens in a South Carolina field study. Miller et al. (2005) conducted a field study about minimal DLI requirements for Tifdwarf and Floradwarf at Florida, which have been reported to be nearly 39 $mol \cdot m^{-2} \cdot d^{-1}$. There also have some unpublished greenhouse study, which related to several warm-season grass minimal DLI requirements. Unfortunately, few longer-term field studies have been conducted to validate these findings over a longer period of time under real world environmental stresses and maintenance conditions.

Mowing Height

From a cultural management perspective, increasing the height of cut within the recommended range for each species can also provide benefit in terms of shade tolerance, as a result of increased carbon uptake via greater leaf area (Dudeck and Peacock, 1992; Bell and Danneberger, 1999; Fry and Huang, 2004). Cutting heights may also result in altered light compensation points of turfgrass due to effects on leaf orientation (Beard, 1973). TifEagle bermudagrass exhibited improved turfgrass quality when maintained at 4.7 mm compared to 3.2 mm in a South Carolina study (Bunnell et al., 2005b). Bunnell et al. (2005a) found that reducing cutting height from 25 to 16 mm significantly decreased turf quality of three bermudagrasses in South Carolina under 71% shade, but not under 41 or 0% shade. Furthermore, significant reductions in carbon fixation were reported when bermudagrass mowing height was changed from 5 cm to 2.5 or 20 cm heights (Alexander and McCloud, 1962).

Plant Growth Regulators

Gibberellin biosynthesis inhibitors such as paclobutrazol {(αR,βR)-rel-β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol}, flurprimidol {α-(1-methylethyl)-α-[4-(trifluoromethoxy)phenyl]-5-pyrimidine- methanol}, and trinexapac-ethyl, have also shown promise in improving quality and persistence of turfgrass in shade (Qian and Engelke, 1999; Stier et al., 1999; Stier and Rogers, 2001; Goss et al., 2002; Steinke and Stier, 2003a; Steinke and Stier, 2003b). Plant growth regulators of this type reduce cell elongation and therefore result in a more compact, dense stand of turfgrass with increased carbohydrate reserves (Qian and Engelke, 1999;

Goss et al., 2002). Trinexapac-ethyl applied at 96 g a.i. ha^{-1} resulted in 96 and 827% more tillers unit area for 'Meyer' zoysiagrass (Zoysia *japonica* Steud.) grown under 77 and 89% shade, respectively (Ervin et al, 2002). Plant growth regulators may also promote other characteristics of turfgrass quality that enhance tolerance to stress (Gardner and Goss, 2013). For example, trinexapac-ethyl has been shown to indirectly improve turfgrass quality through increased leaf rigidity, resulting in improved wear tolerance and improved lateral growth (Stier and Rogers, 1999; Steinke and Stier, 2003a; Steinke and Stier, 2003b).

Nitrogen Rate

Nitrogen fertilizer management can also be an important component to successful shade management. Nitrogen is a driver of plant growth, and is the most dynamic and important nutrient for turfgrasses considering its effects on color, density, recuperative ability, and plant health when applied at adequate rates (Carrow et al., 2001; Hull and Liu, 2005; Liu et al., 2008). Reducing turfgrass N inputs has proven beneficial for light-limited environments. Burton et al. (1959) reported that a high N rate (294 kg ha^{-1} Yr^{-1}) in 64% shade decreased 'Coastal' bermudagrass carbohydrates by 30% and also decreased plant density and leaf area compared to a low N rate (36 kg $ha^{-1}Yr^{-1}$). Similarly, Baldwin et al. (2009) reported significantly improved 'Champion' ultradwarf bermudagrass quality in shade when turf was supplied with 40% reduced N inputs (147 kg N ha^{-1} yr^{-1}) (McCarty and Miller, 2002). Similar benefits from reduced N in shade have also been reported for cool-season turf-grasses (Schmidt and Blaser, 1967; Bell and Danneberger, 1999; Goss et al., 2002).

Although reduced N rates and growth regulators have shown promise when used alone on shaded warm-season turf, the extent to which combinations of the two may be utilized to optimize sports-type bermudagrass cultivars is an area of research that has not been fully explored. Bermudagrass has a relatively high N requirement relative to other turf species (Cisar, Snyder, & Park, 2007), and as such, may not tolerate reduced N inputs in shade, especially in highly trafficked athletic turf situations. Therefore, it would be of interest to examine the extent to which both N and growth regulators could be used in combination to achieve optimal turf quality for shaded athletic turf cultivars.

Currently, there is a need for research-based information that can aid data-driven decisions regarding appropriate turfgrass species/cultivar selection for various shade environments, whether during construction or renovation of golf courses, athletic fields, or lawns. This information could be useful for guiding pruning or tree cutting programs where minimum light thresholds must be achieved relative to existing turfgrass. Understanding the light requirements and limitations of various species/cultivars could also increase the overall sustainability of turfgrass systems by minimizing failure and need for reestablishment of shaded areas due to inappropriate cultivar selection and/or management.

CHAPTER II

DAILY LIGHT INTEGRAL REQUIREMENTS FOR ZOYSIAGRASS AND BERMUDAGRASS CULTIVARS: MOWING HEIGHT AND GROWTH REGULATOR INTERACTIONS

Overview

Shade is one of the greatest turf management concerns for many turf managers. Proper turfgrass selection for shaded areas can be challenging due to difficulty in quantifying necessary light levels particular to each unique environment. Biologically speaking, rather the responding to a number of hours of sunlight or percent shade level, plants ultimately respond to the cumulative daily total number of photons (mols m^{-2} d^{-1}) received within the photosynthetically active wavelengths (400-700 nm), termed 'daily light integral' (DLI). Most prior DLI studies have been with bermudagrass putting greens and shorter-term greenhouse studies. This field study was conducted over multiple seasons under replicated treatments offering 0 to 90% reductions in photosynthetic photon flux (PPF). Furthermore, the effects of growth regulator applications were tested on improving performance of these cultivars in shade. Objectives of this research were to 1) determine minimal DLI requirements for 10 warm-season turf cultivars commonly used on golf courses and sports turf, 2) determine the influence of mowing height (1.9cm vs. 5cm) and trinexapac-ethyl (TE) on minimal DLI requirements, 3) determine whether minimal DLI requirements change seasonally, and 4) determine effects of shade treatments on air and soil temperatures within the turf canopy. Our results demonstrated that zoysiagrass cultivars achieved superior turf quality and had overall lower DLI requirements than bermudagrass cultivars under moderate to heavily (50-90% shade) shaded conditions. Zoysiagrass performance varied by cultivar and between seasons. Most bermudagrass cultivars were able to maintain acceptable quality only in full sun or 30% shade conditions, and Tifway lacked shade tolerance relative to the other bermudagrass cultivars used. Monthly TE application (0.2 kg ai ha^{-1} per month) during summer and increased mowing heights simulating golf course rough also improved turf quality and performance of all cultivars under low-light conditions. Seasonal differences in DLI were noted across all cultivars, with highest DLI requirements observed in summer and reduced DLI occurring in spring and fall seasons. Collectively, the data provide useful information that can be used to guide more accurate, seasonally based recommendations on appropriate species and cultivar selection for shade environments.

Introduction

Selecting appropriate species and cultivars as well as application of effective cultural management strategies for managing turfgrass in shaded environments are important aspects of sustainable turf management. Managing turf in shade can be challenging due to difficulty in precisely quantifying light levels particular to each environment as well as lack of data on minimal light requirements of turfgrass species and cultivars. Complexity variability among shade environments make it difficult to specify a minimum light requirement in terms of 'hours per day' or 'percent shade' tolerable by a specific cultivar that can extend across various situations.

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From a cultural management perspective, increasing the height of cut within the recommended range for a given species can also provide benefit in terms of shade tolerance, as a result of increased carbon uptake via greater leaf area (Dudeck and Peacock, 1992; Bell and Danneberger, 1999; Fry and Huang, 2004). Cutting heights may also result in altered light compensation points of turfgrass due to effects on leaf orientation (Beard, 1973). TifEagle bermudagrass exhibited improved turfgrass quality when maintained at 4.7 mm compared to 3.2 mm in a South Carolina study (Bunnell et al., 2005b). Bunnell et al. (2005a) found that reducing cutting height from 25 to 16 mm significantly decreased turf quality of three bermudagrasses in South Carolina under 71% shade, but not under 41 or 0% shade. Furthermore, significant reductions in carbon fixation were reported when bermudagrass mowing height was changed from 5 cm to 2.5 or 20 cm heights (Alexander and McCloud, 1962).

Plant growth regulators (PGRs) are widely used in turf management programs for reducing shoot growth and frequency of mowing and/or seedhead suppression. Gibberellin biosynthesis inhibitors such as paclobutrazol {(αR, βR)-rel-β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol}, flurprimidol {α-(1-methylethyl)-α-[4-(trifluoromethoxy)phenyl]-5-pyrimidine- methanol}, and trinexapac-ethyl, have shown promise in improving quality and persistence of turfgrass in shade (Qian and Engelke, 1999; Stier et al., 1999; Stier and Rogers, 1999; Goss et al., 2002; Steinke and Stier, 2003a; Steinke and Stier, 2003b). Plant growth regulators of this type reduce cell elongation and therefore result in a more compact, dense stand of turfgrass with increased carbohydrate reserves (Qian and Engelke, 1999; Goss et al., 2002). Trinexapac-ethyl applied at 96 g a.i. ha^{-1} resulted in 97 and 827% more tillers unit area for 'Meyer' zoysiagrass (Zoysia *japonica* Steud.) grown under 77 and 89% shade, respectively (Ervin et al, 2002). Additionally, plant growth regulators may promote other characteristics of turfgrass quality that enhance tolerance to stress (Gardner and Goss, 2013). For example, trinexapac-ethyl has been shown to indirectly improve turfgrass quality through increased leaf rigidity, resulting in improved wear tolerance and improved lateral growth (Stier and Rogers, 1999; Steinke and Stier, 2003a; Steinke and Stier, 2003

b).

The objectives of this field research were to 1) determine minimal DLI requirements for 10 warm-season turf cultivars commonly used on golf courses and sports turf, 2) determine the influence of mowing height (1.9cm vs. 5cm) and trinexapac-ethyl on minimal DLI requirements, 3) determine whether minimal DLI requirements change seasonally, and 4) determine effects of shade treatments on air and soil temperatures within the turf canopy.

Materials and Methods

This research was conducted at the Texas A&M Turfgrass Field Research Laboratory, College Station, TX. A 1394 m^2 shade research facility was constructed in

July 2015. The site was laser-graded to a 0.5% slope to facilitate surface drainage and irrigation installed. Soils at the site were characterized as a Lufkin fine sandy loam (Fine, smectitic, thermic Oxyaquic Vertic Paleustalfs).

Two parallel studies were simultaneously conducted; a ‘rough’ study which was conducted under taller mowing heights (5 cm), and a ‘fairway/tees’ study was managed under shorter height of cut (1.9 cm) typical of fine golf or athletic field turf management. Reel mowers were used for the fairway/tee plots, while rotary mowers were used for rough height plots. Clippings were removed to reduce potential for contamination of neighboring cultivar/specie plots.

The studies were arranged as a completely randomized design with four replicate plots per treatment, and using six shade levels (0= no shading, 30, 50, 70, 80, 90% photosynthetic photon flux reduction) as the whole plot factor. Density neutral shade structures covered plots throughout the duration of the project, and were removed only for short periods in order to maintain plots or collect data. Shade fabric was tightly secured to rolling metal frames using zip ties and were positioned parallel to the ground at a height of 40 cm above ground level. Metal wire was used to reinforce fabric in order to prevent any sagging of shade fabric.

The turfgrasses utilized in this project consisted of both golf course fairway/tees and rough cultivars commonly used across the southern and transition zones of the U.S. Turf cultivars included the following: ‘Tifway’, ‘Tifgrand’, ‘Celebration’ and ‘Latitude 36’ bermudagrass (*Cynodon* spp.); ‘Zeon’, ‘Zorro’, ‘Geo’ zoysiagrass (fine-textured *Z. matrella*); and ‘Palisades’ and ‘JaMur’ zoysiagrass (med-coarse textured *Z. japonica*).

‘Palmetto’ St. Augustinegrass was also included as a shade-tolerant industry standard check (Table 1). Washed sod for each cultivar was established in plots on 12 August 2015, and provided 6-weeks to establish under full sun conditions, with irrigation provided as needed to encourage rapid establishment and prevent wilt during this time. On 23 Sep 2015, shade structures were moved over top of treatment plots.

Table 1. Species, Cultivars and Developers in the field study.

Species	Cultivar	Origin
Bermudagrass	Tifway	University of Georgia
(*Cynodon* spp.)	TifGrand	University of Georgia
	Latitude 36	Oklahoma State University
	Celebration	Sod Solutions, Inc.
Zoysiagrass	Zeon	BladeRunner Farms, Inc.
(Zoysia spp.)	Zorro	Texas AgriLIFE Research
	Palisades	Texas AgriLIFE Research
	JaMur	Texas AgriLIFE Research
	Geo	BladeRunner Farms, Inc.
St. Augustinegrass	Palmetto	Sod Solutions, Inc.
(*Stenotaphrum secundatum*)		

Plots were irrigated from April through October at levels of 0.6 x historical reference evapotranspiration (ET_o) for College Station, TX, based on data from the Texas ET Network (www.texaset.tamu.edu). Plots were irrigated twice weekly with covers in place, with amounts adjusted to account for rainfall events. Depending on growth rates, mowing occurred 1-2 times weekly during the early morning hours so as to minimize time structures were removed from plots during peak solar radiation periods.

Soil tests were performed prior to establishing plots, and soil amended using a micronutrient fertilizer (K Step Hi Mag) in order to achieve sufficiency levels of all nutrients. During the study period, fertilizer applications were made uniformly across all plots to supply 37 kg N ha^{-1} every six weeks from May-October (~150 kg N ha^{-1} annually) using a 21-7-14 50% sulfur-coated urea source (American Plant Food Corp., Galena Park, TX). Preventative fungicide applications (Pillar G, BASF, Research Triangle Park, NC) were made to plots every 3-4 weeks from April through November to prevent disease pressure from affecting plots. Pre-emergence herbicides (Ronstar G, Bayer, Research Triangle Park, NC) were applied in February and September of each year to prevent summer and winter annual weeds. During the study period, between plot contamination of different cultivars was prevented by maintaining a 15 cm wide alley between plots that was sprayed twice monthly using glyphosate. Within shade level main plots, nine cultivars were randomly arranged into 0.9 m x 1.8 m subplots. Within the fairway/tees study, cultivar subplots were further divided into plots receiving monthly application of trinexapac-ethyl (Primo) (Syngenta, Greensboro, NC) at a rate of either 0 or 0.2 kg ai ha^{-1}, applied to select plots using a CO_2 powered backpack sprayer with XR Teejet 8002VS nozzles (Spraying System Co., Wheaton, IL) at 40 psi.

PAR light meters (PAR Smart Sensor, Onset Computer Corporation, MA) and data loggers (HOBO Micro Station Data Logger, Onset Computer Corporation, MA) were positioned within each shade treatment (at a height of 20 cm above the turf canopy) in order to record and quantify DLI over the course of the study. In addition, data loggers recorded 0-3 cm depth soil temperatures as well as air temperatures at 20 cm height above turf canopy (12-Bit Temperature Smart Sensor, Onset Computer Corporation, MA). Soil temperatures were recorded for all shade treatments, but air Temperatures were recorded only within Full Sun and 50% shade treatments due to a limited number of data logger port openings.

Soil and air temperature data were collected on 15-minute intervals over the enter study period. Mean, maximum, and minimum temperatures were calculated for each month of the study within each treatment. During the study, digital light box images of plots were obtained monthly using a digital camera (Canon PowerShot SX-170 IS, Tokyo, Japan) which was mounted on a 0.6 m x 0.6 m x 0.6 metal light box equipped with 4 compact fluorescent bulbs. Images were then used to quantify percent green cover through Sigma Scan Pro (Systat Software, Inc., San Jose, CA) digital analysis using the Turf Analysis macro (Karcher and Richardson, 2003).

Visual turf quality ratings were also taken monthly during the study using a 1 to 9 scale where 1 = dead brown turf, 9 = optimal turf, and a rating $\geq$ 5.5 denoted acceptable quality. For determining minimal monthly and seasonal DLI requirements for each cultivar, nonlinear regression analysis was performed using turf quality and DLI data in Sigma Plot (Systat, Inc., San Jose, CA).

For assessing performance and minimal DLI requirements by season, both percent green cover and turf quality data were pooled across months within seasons. September-November data were pooled for fall, March-May data were pooled for spring, and June-August data were pooled for summer.

Normalized difference vegetation index was also measured monthly for a representative area of each plot using the TCM 500 NDVI Turf Color Meter, Spectrum, IL).

In October 2016, 5 cm diameter x 30 cm depth root samples were taken from the center of full sun and 50% shade treatment plots in the fairway study plots using a Hydraulic Giddings Probe. Root samples were carefully separated from soil using sieves and then oven dried at 65 ^{o}C for 72 hours before weighing to determine root dry weights.

Shear strength data were also taken in October 2016 using a shear vane apparatus (TSHEAR2-M Turf-Tec Shear Strength Tester, Turf-Tec International, Tallahassee, FL) in order to determine stability and shear strength of each cultivar as affected by shade level and trinexepac-ethyl. Turf quality, percent green cover, and root dry weight data were regressed against shade level to identify critical DLI thresholds for each entry at the end of the project.

Data were collected monthly from September 2014 through December 2016, and are presented by month as well as by season. Data for each parameter were subjected to analysis of variance using the general linear model, univariate test procedure of SPSS ver. 21.0 (IBM Corp, Armonk, NY) to determine statistical significance of the results. Where analysis of variance indicated a significant treatment effects or interactions mean separation procedures were performed using Fisher's Least Significant Difference test at the $P \leq 0.05$ level.

Results

Soil Temperatures

ANOVA revealed a significant month x shade level interaction, as well as significant month and shade level main effects for mean soil temperatures (Table 2). Soil mean temperatures were generally highest in Full Sun, with differences between treatments most apparent in February, when 90% shade temperatures were considerably lower than other shade treatments. For the month of August Full Sun plot temperatures were considerably higher than other shade treatments (Figure 1).

ANOVA revealed a significant shade level main effect for maximum soil temperatures (Table 2). Full Sun had the highest monthly maximum temperatures throughout 2016 (Figure 2). Soil maximum temperature generally decreased with increasing shade level hade level increasing (Figure 2). The one exception to this was that the 80% shade treatment showed similar maximum temperatures to the 70% shade treatment; however, both were still intermediate to the 50 and 90% shade treatments.

ANOVA also detected a significant month x shade level interaction, as well as significant month and shade level main effects for soil minimum temperatures (Table 2). Soil minimum temperatures were generally highest in Full Sun, with differences between treatments most apparent in February, when 90% shade exhibited considerably lower minimum soil temperatures than other shade treatments, and August, when Full Sun plots had considerably higher minimum temperatures than other shade treatments (Figure 3).

Air Temperatures

ANOVA revealed a significant month main effect for air mean and minimum temperatures. There was also a significant month x shade level interaction, as well as significant month and shade level main effects observed for maximum air temperatures (Table 2). Air maximum temperatures were generally highest in 30% shade during summer months, but by October and throughout the fall months, 90% shade exhibited the highest maximum air temperatures (Figure 4). The greatest air maximum temperature differences between treatments occurred in October, where 90% shade exhibited considerably higher temperatures than other shade treatments (Figure 4).

Table 2. ANOVA for soil and air Mean, Maximum, and Minimum Temperatures for the 2016 season.

	Soil Mean Temp	Soil Max Temp	Soil Min Temp	Air Mean Temp	Air Max Temp	Air Min Temp
Month	***	***	***	***	***	***
Shade Level	***	***	***	NS	***	NS
Month x Shade Level	**	NS	*	NS	***	NS

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS, not significant at $P \leq 0.05$.

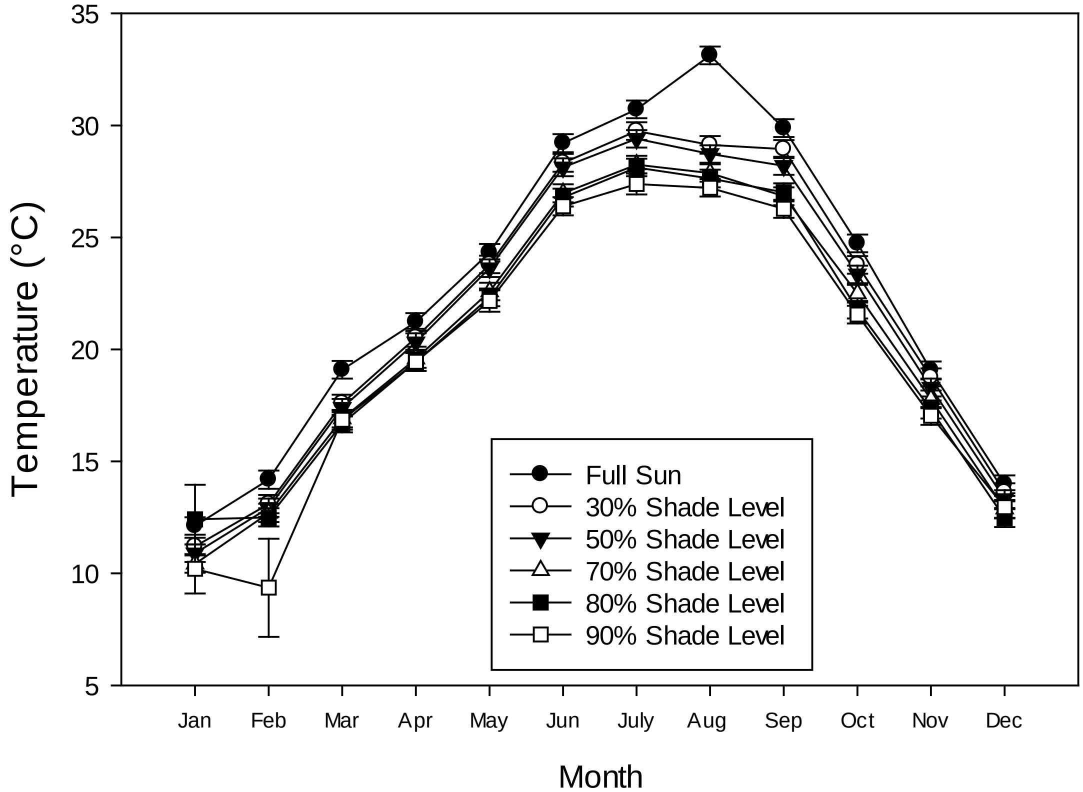

Figure 1. Soil Mean Temperatures by month for field shade treatment plots during 2016. Temperatures were recorded at the 0-2.5 cm depth with measurements taken every 15 minutes. Error bars denote standard error.

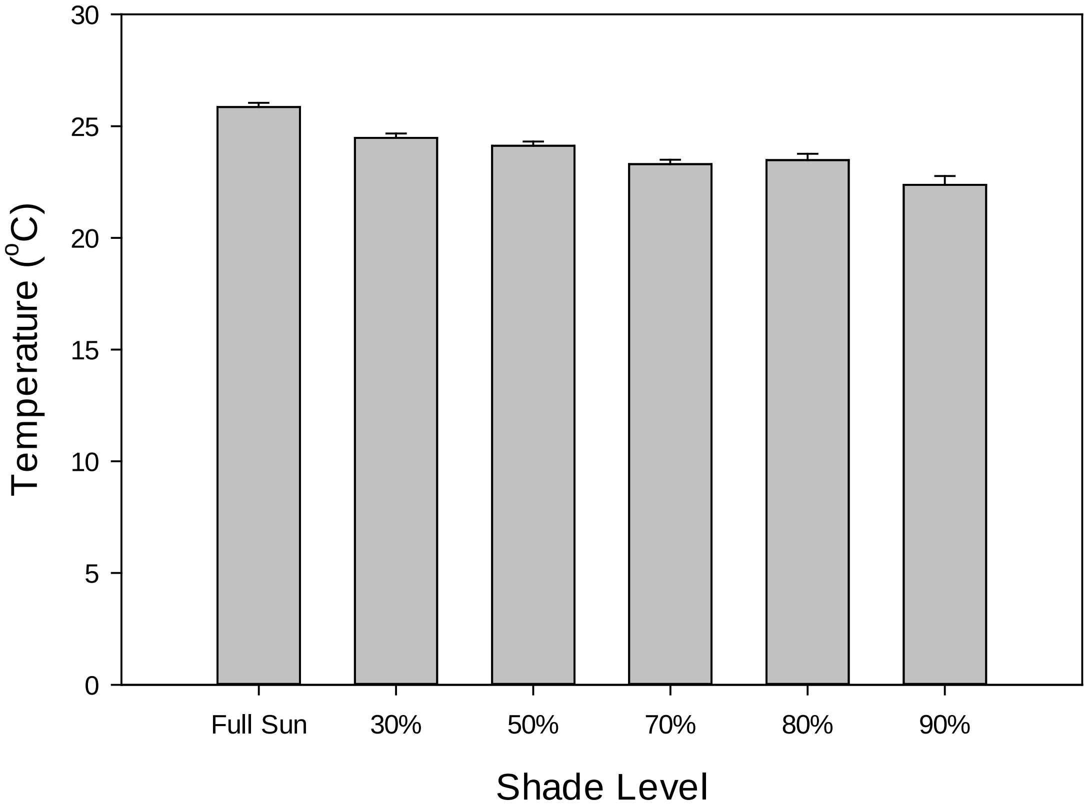

Figure 2. Soil Maximum Temperatures by shade level for the field study during 2016. Data are pooled across month. Error bars denote standard error.

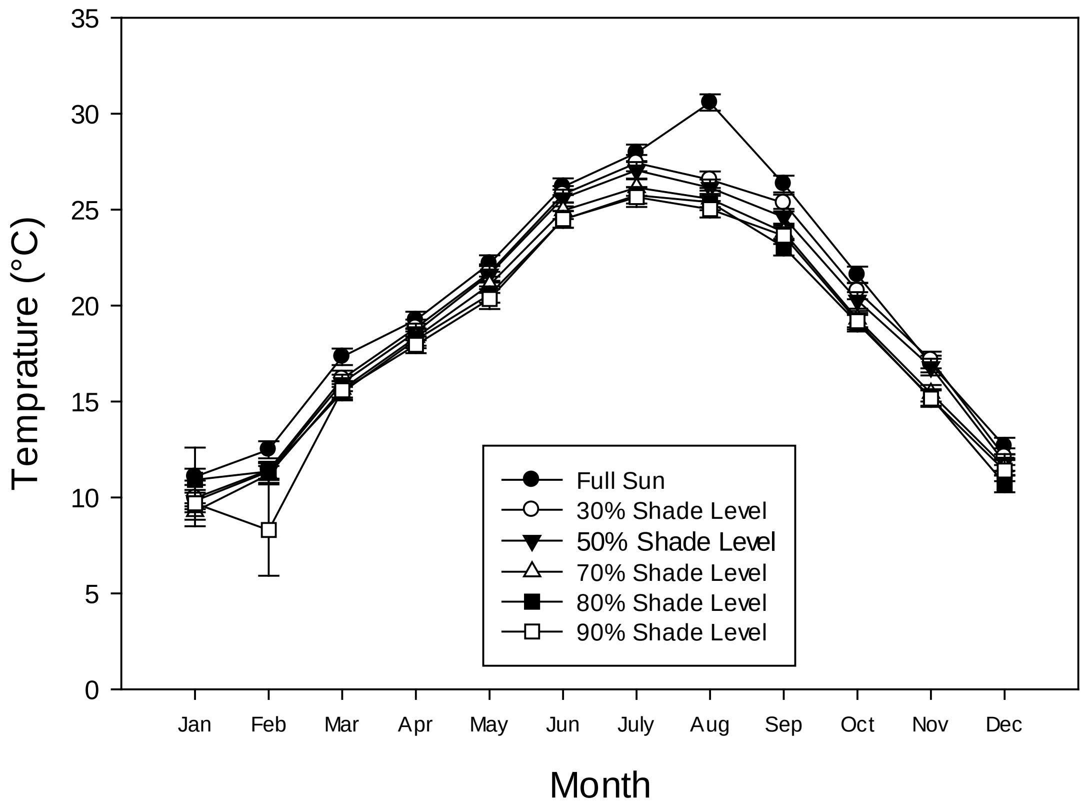

Figure 3. Soil Minimum Temperature by month for field shade treatment plots during 2016. Temperatures were recorded at the 0-2.5 cm depth with measurements taken every 15 minutes. Error bars denote standard error.

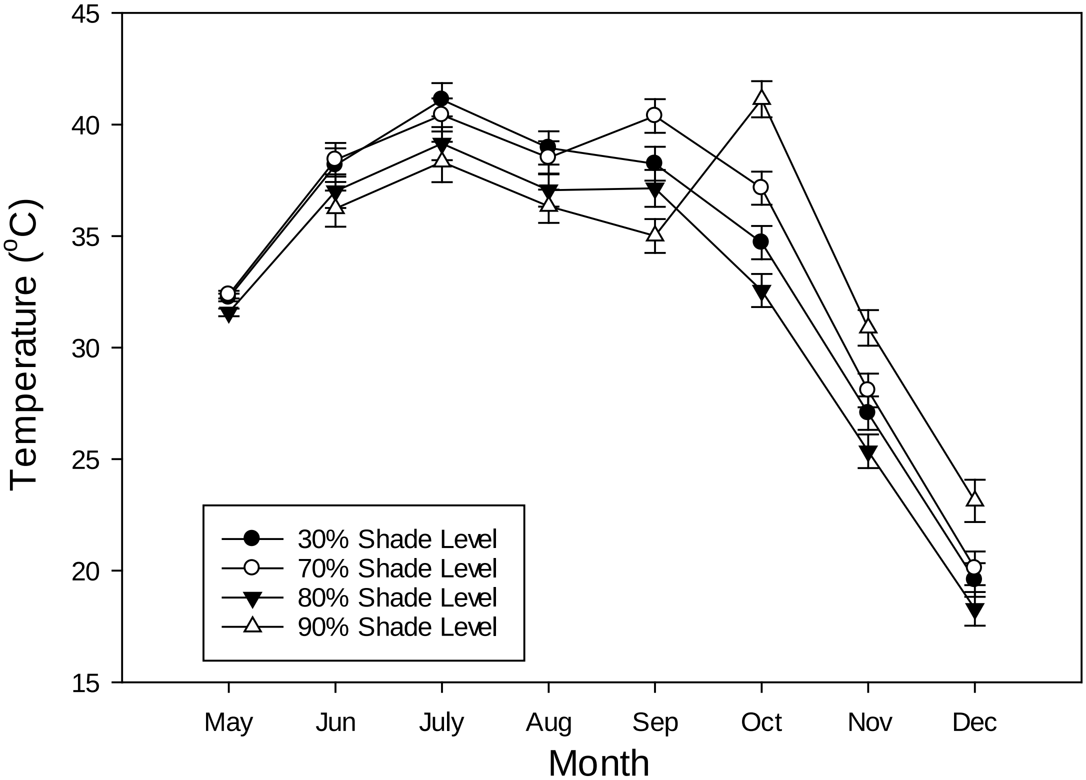

Figure 4. Air Maximum Temperatures by month for field shade treatment plots during 2016. Temperatures were recorded at the 0-2.5 cm depth with measurements taken every 15 minutes. Error bars denote standard error.

Percent Green Cover

Fall 2015

Fall 2015 fairway ratings, which were pooled across September and October rating dates, there were significant cultivar effects for all shade treatments except for 70% shade (Table 3). In full sun, Palisades and Latitude 36 exhibited the greatest percent green cover (~65%), significantly outperforming both Tifway and TifGrand. In 30% shade, Geo, Palisades, and Latitude 36 had the greatest percent green cover (at or above 60%), and each outperformed Tifway. In 50% shade, Geo maintained the highests (73.3%) green cover exceeding that of Tifway (25.3%). Geo also had the greatest percent green cover in 80% shade (51.6%). In contrast, Tifway had the lowest percent green cover in 80% shade, which was significantly lower than Zorro, Palisades, JaMur and Geo. In 90% shade, Palisades and Latitude 36 (40.1 and 37.7% green cover, respectively) maintained the greatest percent green cover, which again, was significantly greater than Tifway.

Fort the rough mowing height, there were significant cultivar effects for percent green cover in all shade treatments (Table 3). Rough mowing height exhibited overall higher percent green cover when compared to fairway mowing height. In full sun, Zeon and Palmetto had the greatest percent green cover, which was significantly greater than that of Tifway. In 30% shade, Palmetto had the greatest percent green cover (88.8%), which was significantly greater than Tifway and TifGrand (54.6 and 61.1%) and Zorro also maintained significantly higher green cover (81.6%) in 30% shade compared to Tifway (54.6%). At 50% shade level, Palmetto again maintained the highest percent green cover (88.4%), significantly greater than that of Tifway, TifGrand and Latitude 36. In 70% shade, Palmetto maintained 80% percent green cover, which was significantly greater than Tifway. In 80% shade, Tifway had the lowest green cover, significantly lower than Zeon, Zorro, Palisades, JaMur and Palmetto, while Palmetto again maintained the highest (79.5%) green cover. In 90% shade, all zoysiagrass cultivars and Latitude 36 bermudagrass maintained greater than 50% green cover, while Tifway again showed the least cover (31.3%). Overall, zoysiagrass cultivars consistently maintained higher levels of green cover across all shade treatments when compared with bermudagrass, while St. Augustine grass cultivar Palmetto had the greatest percent green cover levels of all entries for Fall 2015 at the Rough mowing height.

Table 3. Percent green cover of each cultivar across shade levels for fall 2015.

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	36.7	30.7	25.3	16.9	14.4	9.5
TifGrand	39.6	44.3	46.4	30.4	30.1	21.2
Celebration	50.4	44.4	48.2	31.9	36.6	26.7
Latitude 36	64.7	60.2	47.9	44.9	35.9	37.7
Zeon	46.3	42.5	37.8	32.6	34.5	21.3
Zorro	49.5	39.4	41.2	40.6	38.1	24.4
Palisades	65.8	65.2	52.3	44.0	41.0	40.1
JaMur	44.1	47.2	50.5	38.5	40.5	25.3
Geo	53.6	66.6	73.3	45.9	51.6	27.5
LSD	25.0	28.0	27.7	28.9	22.6	24.0
Cultivar	**	**	***	NS	**	*
			Rough			
Tifway	62.5	54.6	49.9	39.6	36.1	31.3
TifGrand	69.0	61.1	62.9	54.3	53.5	45.2
Celebration	70.8	71.7	70.7	55.4	62.0	48.7
Latitude 36	70.9	64.5	62.2	52.2	57.9	53.6
Zeon	89.1	77.7	71.2	73.0	68.0	69.0
Zorro	75.4	81.6	73.6	55.9	73.2	63.4
Palisades	81.1	70.6	68.2	60.7	72.4	60.8
JaMur	78.8	77.3	73.6	66.1	72.2	67.5
Palmetto	90.1	88.8	88.4	79.5	79.5	68.6
LSD	24.5	26.3	24.9	34.5	31.9	36.0
Cultivar	*	**	**	*	**	*

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Spring 2016

Spring 2016 consisted of March and May rating dates. At the fairway mowing height, there were significant cultivar effects within all shade treatments (Table 4). In full sun, Geo exhibited the lowest percent green cover, significantly lower than TifGrand, Zeon, Zorro and Palisades. Zorro had the highest percent green cover (87.1%) in full sun.. For 30% shade, Tifway had the lowest percent green cover (23.5%), significantly lower than that of Zeon, Zorro, Palisades and JaMur zoysiagrasses. Zorro maintained the highest percent green cover (83.3%) in 30% shade, significantly greater than that of Tifway, TifGrand, Celebration and Latitude 36. Zeon maintained significantly greater green cover in 30% shade than Latitude 36 (81.4 vs. 26.6%, respectively). At 50% shade, Tifway continued to have the lowest percent green cover (13.6%), significantly lower than that of Zeon, Zorro, Palisades and JaMur. Zorro and Zeon each maintained greater than 70% green coverage in 50% shade, and were significantly greater than Tifway, TifGrand, Celebration, Latitude 36, Palisades and Geo. In 70% shade, Zorro and Zeon again had the highest percent green cover, significantly greater than that of Tifway, Celebration, Latitude 36 and Geo. JaMur possessed significantly greater green cover in 70% shade compared to Tifway, Celebration and Latitude 36. Trends were similar in 80% shade. As such, Zorro and Zeon had the highest percent green cover, significantly greater than that of Tifway, Celebration, Latitude 36 and Geo. Finally, in 90% shade, Zorro maintained the greatest percent green cover, significantly greater than that of Tifway, TifGrand, Celebration, Latitude 36 and Geo. Also, Palisades and Zeon green cover were significantly greater than that of

Tifway, Latitude 36 and Geo. Overall, Zorro and Zeon maintained the highest levels of green cover for most shade treatments mowed at fairway mowing height during Spring 2016.

Within the rough mowing height, there were also significant cultivar main effects within all shade treatments (Table 4). Rough mowing height produced overall higher percent green cover compared to fairway height, especially in the heavier shade treatments. In full sun, Zorro had the highest percent green cover (90%), significantly greater than that of Tifway, TifGrand and Celebration. Also in full sun, Palmetto maintained 82.8% green cover, significantly greater than that of Tifway and TifGrand. In 30% shade, Zorrohad the highest percent green cover (95.3%), significantly greater than that of Tifway, Celebration and Latitude 36. Tifway also had significantly lower green cover in 30% shade than TifGrand, Latitude 36, Zeon, Palisades, JaMur and Palmetto. Within 50% shade, Zeon and Zorro had the highest percent green cover (~90%), significantly greater than that of Tifway, TifGrand, Celebration and Latitude 36. Tifway had the lowest percent green cover in 50% shade, significantly lower than all other cultivars. In 70% shade, Zeon, Zorro and JaMur had the highest percent green cover, significantly greater than that of all bermudagrass cultivars. Within the bermudagrasses, TifGrand maintained 51.5% green cover in 70% shade, which was significantly greater than Tifway. Also, Palisades and Geo exhibited significantly greater green cover in 70% shade than Tifway. Within 80% shade, Zorro had the highest percent green cover (78.8%), significantly higher than all bermudagrass cultivars and Palisades zoyisagrass. Tifway had the lowest percent green cover in 80% shade, significantly lower than that of

Celebration, Zeon, JaMur and Palmetto. In 90% shade, Zeon maintained the highest percent green cover (59.5%), which was significantly greater than all bermudagrass cultivars, Palisades zoysiagrass, and even Palmetto St. Augustinegrass. Overall, during the spring 2016 rating months within the rough mowing height, Tifway bermudagrass consistently exhibited the lowest percent green cover in shade, and had inferior performance to Celebration, Latitude 36, Zorro, JaMur and Palmetto. JaMur also had significantly higher percent green cover when compared to Latitude 36, Palisades and Palmetto for most shade levels when mowed at rough height in spring 2016.

Table 4. Percent green cover of each cultivar across shade level for spring 2016.

	Full Sun	30%	50%	70%	80%	90%
				Fairway		
Tifway	58.9	23.5	13.6	4.7	3.4	3.1
TifGrand	78.7	49.4	32.3	26.6	12.1	8.5
Celebration	71.5	39.6	27.2	9.8	9.0	5.8
Latitude 36	51.2	26.6	17.6	6.4	12.6	3.2
Zeon	77.9	81.4	71.2	45.4	32.8	15.7
Zorro	81.1	87.1	83.3	47.7	40.6	20.6
Palisades	79.3	60.7	50.5	26.4	20.4	11.0
JaMur	60.4	62.7	63.3	35.6	22.9	15.4
Geo	47.1	53.1	38.0	16.8	4.1	1.8
LSD	29.3	36.8	30.7	22.4	20.4	11.9
Cultivar	**	***	***	***	***	***
				Rough		
Tifway	51.5	39.4	29.3	24.4	21.1	11.0
TifGrand	52.9	78.2	62.8	51.5	42.0	28.7
Celebration	60.7	63.3	61.9	44.6	48.9	35.5
Latitude 36	72.2	66.7	52.9	44.3	37.2	31.7
Zeon	73.3	88.8	89.9	82.9	57.4	59.5
Zorro	89.9	95.3	91.4	76.9	78.8	43.3
Palisades	70.8	81.7	70.5	48.5	36.0	28.2
JaMur	70.0	84.5	86.1	73.9	60.6	53.0
Palmetto	82.8	87.8	77.9	58.5	51.9	26.4
LSD	27.4	24.8	23.4	22.8	27.5	20.5
Cultivar	***	***	***	***	***	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Summer 2016

Summer 2016 data are pooled across June, July and August rating dates, and where significant cultivar x primo interactions were significant, percent green cover data for each cultivar are split by primo (Table 5). During summer 2016, primo applications (applied only to fairway height plots) showed significant main effects on percent green cover in full Sun, 30%, 50%, 70% and 80% shade treatments. Also, there were significant cultivar main effects in all treatments except full sun. In general, zoysiagrass cultivars also had higher percent green cover than bermudagrass cultivars in summer 2016. In 30% shade, JaMur had the highest percent green cover (74.7%), significantly greater than that of Tifway, Celebration and Latitude 36 bermudagrasses. TifGrand had the highest percent green cover (66.5%) within 30% shade among the bermudagrass cultivars, significantly greater than thata of Tifway. In 50% shade, JaMur maintained the greatest percent green cover (> 50%) both 50% and 70% shade,significantly greater than that of all bermudagrass cultivars. In 80% shade, Zorro had the highest percent green cover, significantly greater than that of bermudagrass cultivars and Geo zoysiagrass. In 90% shade, Zorro and JuMur each had the greatest percent green cover (17.5 and 19.5%, respectively) and were significantly greater than cultivars Tifway, Celebration, Latitude 36, Palisades and Geo.

For rough mowing height, there were significant cultivar effects across 30% to 90% shade treatments (Table 5). In 30% shade, zoysiagrass cultivars exhibited better percent green cover than bermudagrass cultivars. Palmetto had the highest percent green cover (77.4%), significantly greater than that of Tifway, Celebration and Latitude 36 bermudagrasses. TifGrand bermudagrass showed the highest percent green cover (52.3%) of the bermudagrasses, significantly greater than that of Tifway and Latitude 36. In 50% shade, Palmetto had the highest percent green cover (69.9%), significantly greater than that of all bermudagrass cultivars, and also had the highest percent green cover (55.6%) in 70% shade, where it exceeded that of all bermudagrasses and Zeon and Zorro zoysiagrass. In 80% shade, Zorro and JaMur had the highest percent green cover, significantly greater than that of all bermudagrass cultivars. JaMur was the only cultivar with greater than 50% green cover (52.1%) in 80% shade. JaMur also had the highest percent green cover in 90% shade, significantly greater than that of all other cultivars except Palisades and Palmetto.

Table 5. Percent green cover of each cultivar and main effect of Primo as affected by shade level for summer 2016. Fairway percent green cover data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
				Fairway		
Tifway	57.1	34.3	32.7	29.7	20.3	4.7
TifGrand	66.5	56.8	42.6	32.0	24.8	11.8
Celebration	59.0	38.6	35.9	27.2	22.8	3.5
Latitude 36	54.9	43.4	39.6	29.2	25.6	6.4
Zeon	69.8	58.7	50.0	36.2	25.9	10.0
Zorro	66.2	60.2	57.1	41.5	40.3	17.5
Palisades	62.7	59.4	61.2	46.2	29.6	9.0
JaMur	74.7	69.2	63.2	51.9	31.3	19.5
Geo	64.8	58.2	55.9	38.2	25.1	7.6
LSD	21.5	21.1	16.4	15.8	14.3	8. 8
-Primo	57.7	49.3	40.1	32.0	23.9	9.2
+Primo	70.2	57.0	57.3	41.8	30.7	10.8
Cutivar	NS	***	***	***	**	***
Primo	***	*	***	***	**	NS
Cutivar*Primo	NS	NS	NS	NS	NS	NS
				Rough		
Tifway	48.5	32.6	21.1	18	25.2	8.4
TifGrand	65.5	52.3	41.7	26.6	21.9	11.8
Celebration	59.1	39.5	45.3	25.4	24.6	5.0
Latitude 36	56.8	30.2	30.9	15.8	26.3	9.5
Zeon	64.8	66.4	58.5	37.7	34.9	12.9
Zorro	60.4	65.7	64.5	35.4	48.3	24.0
Palisades	58.2	63.9	59.5	43.2	45.3	27.0
JaMur	67.8	69.6	62.1	45.3	52.1	39.1
Palmetto	80.0	77.4	69.9	55.6	46.1	26.0
LSD	28.8	16.5	16.4	15.3	22.3	13.2
Cultivar	NS	***	***	***	***	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Fall 2016

Fall 2016 data consist of September, October and November rating dates. At the fairway mowing height, there was a significant cultivar effect on percent green cover across all shade treatments (Table 6). Once again, zoysiagrass cultivars generally had higher percent green cover than bermudagrass cultivars in moderate and heavy shade environments. ANOVA showed a Primo main effect on percent green cover, and as such, Primo benefited green cover in all shade treatments. In full sun, Geo exhibited the highest percent green cover (86.6%), significantly greater than that of Tifway. Within the bermudagrass cultivars, TifGrand, Celebration and Latitude 36 all had significantly greater green cover than Tifway. In 30% shade, JaMur showed the greatest percent green cover (81.5%), significantly greater than that of all bermudagrass cultivars. Also, TifGrand and Celebration had a significantly higher green cover than Tifway in 30% shade. In 50% shade, Geo had the highest percent green cover (83.7%) significantly greater than all bermudagrass cultivars. Also in 50% shade, Tifway had significantly less percent green cover than other Bermudagrass cultivars. In 70% shade, Geo had the highest percent green cover (67.6%) significantly greater than other bermudagrass cultivars. Also in 70% shade, TifGrand maintained significantly higher green cover than Tifway (38.2 vs. 20.5, respectively). In 80% shade, Zorro, Palisades, and JaMur were the only cultivars to maintain above 50% green cover. In 90% shade, zoysiagrass cultivars had significantly greater percent green cover than bermudagrass cultivars.

In general, the rough mowing height led to greater percent green cover than fairway mowing height for most entries (Table 6). Zoysiagrass cultivars also had higher percent green cover than bermudagrass cultivars under moderated to heavy shade environments. Zeon, Palisades, JaMur and Palmetto all had the highest percent green cover in full sun, and had significantly greater cover (>84%) than Tifway. Palisades, JaMur, and all bermudagrass cultivars in 30% shade. In both 50 and 70% shade, Palisades, JaMur and Palmetto all had the highest percent green cover (>70%) significantly greater than that of all bermudagrass cultivars. Celebration had the highest percent green cover of all bermudagrasses, signficantly greater than that of Tifway. Within 80% shade, Zorro, Palisades, JaMur and Palmetto all maintained more than 60% green cover significantly more than all bermudagrass cultivars. In 90% shade, all zoysiagrass cultivars had significantly greater green cover than all bermudagrass cultivars. JaMur was the only entry to maintain >50% green cover (52.2%) in 90% shade levels.

Table 6. Percent green cover of each cultivar and main effect of Primo as affected by shade level for fall 2016. Fairway percent green cover data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	58.2	46.2	37.7	20.5	15.2	13.3
TifGrand	78.9	68.8	61.2	38.2	22.1	14.1
Celebration	76.3	60.6	58.0	33.6	26.6	12.9
Latitude 36	76.2	55.2	52.6	34.0	27.1	11.7
Zeon	74.5	69.9	67.9	53.3	40.8	30.1
Zorro	79.7	72.8	72.6	65.9	54.2	34.7
Palisades	83.9	76.1	75.8	64.1	50.9	24.3
JaMur	86.1	81.5	76.8	65.0	52.8	35.5
Geo	86.6	73.0	83.7	67.6	49.0	33.3
LSD	14.2	12.8	12.7	13.7	16.6	11.7
-Primo	75.1	64.4	61.4	44.4	34.8	20.1
+Primo	80.6	70.1	68.9	53.8	40.5	26.5
Cultivar	***	***	***	***	***	***
Primo	*	**	***	***	*	***
Cultivar*Primo	NS	NS	NS	NS	NS	NS
			Rough			
Tifway	63.3	63.1	45.6	27.5	27.7	13.1
TifGrand	78.9	70.9	65.3	45.4	28.8	13.1
Celebration	71.9	71.2	70.5	57.2	41.3	11.8
Latitude 36	73.3	68.4	66.4	42.8	37.7	13.7
Zeon	84.1	72.6	70.9	67.0	51.2	31.3
Zorro	77.3	78.8	72.9	63.4	65.6	36.4
Palisades	85.9	84.9	82.2	73.8	64.6	48.6
JaMur	86.5	83.6	85.5	72.0	68.3	52.2
Palmetto	87.7	81.4	82.1	76.6	70.2	43.9
LSD	15.8	12.5	11.2	12.2	17.6	13.6
Cultivar	***	***	***	***	***	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Turfgrass Quality

Fall 2015

For fall 2015, which consisted of September and October rating dates, there were significant cultivar effects on turf quality in full sun, 70%, and 80% shade treatments at fairway mowing heights (Table 7). In full sun, all cultivars had acceptable turf quality. Palisades had the greatest turf quality (6.6), significantly greater than TifGrand, Tifway and JaMur. In 70% shade, Palisades, Zorro, Zeon and Latitude 36 had the greatest turf quality, significantly greater than that of Tifway. In 80% shade, Zeon, Zorro, Palisades and Latitude 36 had the greatest turf quality (~5.8), significantly greater than that of Tifway. Across all the shade treatments, Latitude 36 had the greatest turf quality among bermudagrass cultivars, and always maintained turf quality above the minimal acceptable turf quality.

During fall 2015, rough mowing heights generally led to higher turf quality than fairway mowing heights, and all cultivars maintained turf quality above minimal acceptable levels (Table 7). At the rough mowing height, there were significant cultivar effects on turf quality in both 30 and 80% shade levels. In 30% shade, Palmetto had the greatest turf quality (6.5) significantly greater than TifGrand bermudagrass. At the 80% shade level, Palisades had the greatest turf quality (6.6), significantly greater than that of Tifway, TifGrand and Celebration.

Table 7. Turf Quality of cultivars as influenced by shade level during fall 2015. Fairway turf quality data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	5.9	5.3	5.4	4.9	4.9	4.9
TifGrand	5.8	5.8	5.6	5.4	5.6	5.4
Celebration	6.1	5.9	5.6	5.5	5.6	5.3
Latitude 36	6.5	6.1	5.9	5.8	5.8	5.6
Zeon	6.2	5.9	5.8	5.9	5.8	5.7
Zorro	6.1	5.6	5.7	5.8	5.6	5.6
Palisades	6.6	6.0	6.0	6.0	5.9	5.9
JaMur	5.8	5.6	5.8	5.4	5.7	5.3
Geo	6.1	6.0	6.2	5.6	5.8	5.3
LSD	0.6	0.8	0.8	0.8	0.8	1.1
Cultivar	**	NS	NS	*	*	NS
			Rough			
Tifway	6.2	5.9	5.9	5.8	5.4	5.5
TifGrand	6.1	5.7	5.9	5.9	5.8	5.7
Celebration	6.3	5.9	6.1	5.9	5.8	5.8
Latitude 36	6.4	5.9	6.0	6.1	5.9	5.9
Zeon	6.5	6.1	6.3	6.3	6.0	6.3
Zorro	6.7	6.4	6.4	6.6	6.2	6.4
Palisades	6.8	6.4	6.6	6.3	6.6	6.3
JaMur	6.3	6.1	6.2	6.1	6.1	5.9
Palmetto	6.6	6.5	6.5	6.4	6.3	6.1
LSD	0.9	0.7	0.8	1.0	0.8	1.02
Cultivar	NS	*	NS	NS	**	NS

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Spring 2016

Spring 2016 data consisted of March and May rating dates. Within the fairway mowing height, there were significant cultivar effects on turf quality within all shade treatments (Table 8). In full sun, Zeon had the greatest turf quality (6.3), significantly greater than that of Tifway. In 30% shade, Zeon and Zorro showed the greatest turf quality (6.0) significantly greater than that of Tifway, TifGrand, Celebration and Latitude 36. In 50 and 70% shade treatments, Zeon and Zorro exhibited significantly better turf quality than all bermudagrass cultivars and Geo zoysiagrass. Zeon, Zorro and JaMur were able to maintain acceptable (>5.5) turf quality in 50% shade when other cultivars dropped below minimal acceptable turf quality. Zeon and Zorro also had the greatest turf quality in 80 and 90% shade, and exceeded that of Tifway and Geo.

Rough mowing heights had generally higher turf quality than fairway mowing heights during spring 2016. ANOVA detected significant cultivar effects turf quality for 30, 50, 70, and 90% shade treatments (Table 8). Zorro and Zeon had the greatest turf quality (6.4 and 6.6, respectively) in 30% shade, significantly greater than that of Tifway, TifGrand and Celebration. In 50% shade, Zeon and Zorro again exhibited the greatest turf quality (~6.3) significantly greater than that of all bermudagrass cultivars. Celebration also showed the greatest turf quality among the bermudagrass cultivars and was significantly greater than Tifway in 50% shade. In 70% shade, Zeon had the greatest turf quality (6.3), significantly greater than that of all others except Zorro. Also, Celebration showed significantly better turf quality than Tifway in 70% shade. Within 90% shade, Zeon and Zorro were the only cultivars to maintain acceptable turf quality

(5.8 and 5.6, respectively), significantly greater than that for Tifway, TifGrand, Palisades and even Palmetto. Also in 90% shade, Celebration and Latitude 36 had the greatest turf quality among the bermudagrasses.

Table 8. Turf quality of cultivars as influenced by shade level during spring 2016.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	5.5	4.9	4.6	4.0	3.8	3.5
TifGrand	5.8	5.3	4.9	4.5	4.4	4.3
Celebration	5.7	4.8	4.8	4.1	4.1	3.9
Latitude 36	5.8	4.8	4.2	4.1	4.3	3.9
Zeon	6.3	6.0	5.8	5.3	4.9	4.4
Zorro	6.2	6.1	5.9	5.2	4.9	4.6
Palisades	6.1	5.8	5.4	4.8	4.4	3.8
JaMur	5.6	5.3	5.5	5.0	4.5	3.9
Geo	5.6	5.7	4.9	4.6	3.8	3.7
LSD	0.8	1.0	0.8	0.8	1.0	0.8
Cultivar	*	***	***	***	**	**
			Rough			
Tifway	5.8	5.3	5.0	5.1	5.1	4.6
TifGrand	5.4	5.5	5.4	5.5	5.4	4.9
Celebration	5.6	5.7	5.6	5.6	5.6	5.4
Latitude 36	6.1	6.1	5.5	5.4	5.4	5.4
Zeon	6.0	6.4	6.3	6.3	5.5	5.8
Zorro	6.6	6.6	6.2	5.9	5.6	5.6
Palisades	5.9	6.0	5.8	5.6	5.4	5.1
JaMur	5.9	6.1	6.1	5.7	5.7	5.4
Palmetto	6.2	6.3	5.9	5.6	5.5	4.9
LSD	1.0	0.6	0.6	0.5	0.5	0.5
Cultivar	NS	***	***	***	NS	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Summer 2016

Summer 2016 data consisted of June, July and August rating dates. At the fairway mowing height, there were significant cultivar effects on turf quality within all shade treatments (Table 9). Additionally, Primo main effect on turf quality was significant at 30%, 50% and 70% shade levels. In full sun, Zeon, Zorro and Geo zoysiagrass exhibited the greatest turf quality (6.5, 6.3 and 6.3, respectively), significantly greater than that for Tifway, Celebration and Latitude 36 bermudagrass. In the 30% shade level, Zeon showed the greatest turf quality (6.0), significantly greater than that for all bermudagrass cultivars. In 50% shade, Zeon, Zorro, Palisades, and JaMur exhibited significantly greater turf quality compared to all bermudagrass cultivars. Also in 50% shade, zoysiagrass cultivars maintained above acceptable turf quality while bermudagass cultivars dropped below acceptable levels. In 70% shade, Zorro and Geo zoysiagrass showed significantly greater turf quality than all bermudagrass cultivars. Also in 70% shade, Zoysiagrass cultivars Zorro and Palisades and bermudagrass cultivars Latitude 36 and TifGrand exhibited the greatest turf quality, significantly greater than that of Tifway. In 90% shade, Zorro zoysiagrass showed the greatest turf quality, significantly greater than that for Tifway bermudagrass.

Rough mowing height generally led to improved turf quality, particularly within 70, 80, and 90% shade levels. ANOVA detected significant cultivar effects on turf quality for full sun, 30, 50, 70, and 90% shade treatments (Table 9). In full sun, Zeon, Zorro, and Palmetto had the greatest turf quality (6.1), significantly greater than that for Tifway, TifGrand, and Celebration. In 30% shade, Zeon and Zorro had the greatest turf quality (5.8), significantly greater than that for TifGrand and Celebration bermudagrass. In 50% shade, Zeon, Zorro and Palmetto again had the greatest turf quality (5.8, 5.7 and 5.7, respectively), significantly greater than that for all bermudagrass cultivars. In 70% shade, Palmetto St. Augustinegrass and all zoysiagrass cultivars except Palisades maintained acceptable turf quality and had significantly improved turf quality compared to all bermudagrass cultivars. In 90% shade, Zorro and JaMur zoysiagrass had the greatest turf quality (5.1), significantly greater than that for Celebration and Tifway bermudagrass.

Table 9. Turf quality of each cultivar and main effect of Primo as affected by shade level for summer 2016. Fairway turf quality data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	5.6	5.4	5.4	4.7	4.0	3.6
TifGrand	5.9	5.6	5.4	5.0	4.6	3.9
Celebration	5.5	5.6	5.2	4.8	4.5	3.9
Latitude 36	5.5	5.6	5.3	5.0	4.8	3.9
Zeon	6.5	6.0	5.7	5.1	4.4	4.1
Zorro	6.3	5.9	5.8	5.3	4.7	4.3
Palisades	6.0	5.9	5.8	5.2	4.6	4.1
JaMur	5.9	5.7	5.9	5.2	4.5	4.1
Geo	6.3	5.7	5.6	5.3	4.4	4.0
LSD	0.5	0.3	0.3	0.3	0.5	0.4
-Primo	5.9	5.6	5.4	4.9	4.5	4.0
+Primo	5.9	5.8	5.7	5.1	4.5	4.1
Cultivar	***	***	***	***	*	**
Primo	NS	**	***	***	NS	NS
Cutivar*Primo	NS	NS	NS	NS	NS	NS
			Rough			
Tifway	5.5	5.4	5.3	5.1	5	4.3
TifGrand	5.6	5.3	5.5	5.2	5.1	4.7
Celebration	5.6	5.3	5.5	5.3	5.1	4.1
Latitude 36	5.7	5.4	5.3	5.0	5.2	4.5
Zeon	6.1	5.8	5.8	5.5	5	4.9
Zorro	6.1	5.8	5.7	5.5	5.3	5.1
Palisades	5.8	5.7	5.5	5.4	5.2	4.8
JaMur	6	5.6	5.5	5.5	5.4	5.1
Palmetto	6.1	5.7	5.7	5.6	5.2	4.5
LSD	0.5	0.5	0.3	0.2	0.5	0.6
Cultivar	**	*	***	***	NS	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Fall 2016

Fall 2016 data consist of September, October and November rating dates. Within the fairway mowing height, there were significant cultivar main effects on turf quality within all shade treatments (Table 10). Also, Primo significantly affected turf quality in all shade treatments. In full sun, Geo, Palisades, and JaMur zoysiagrass exhibited the greatest turf quality (6.4), significantly greater than that of Tifway. In 30% shade, Geo had the greatest turf quality, significantly greater than that of all bermudagrass cultivars. Tifway bermudagrass dropped below the acceptable level of 5.5 when the shade level reached 30% or greater. In 50% shade, Palisades and Geo exhibited the greatest turf quality, significantly greater than that for all bermudagrass cultivars. In 70% shade, Geo had the greatest turf quality and still maintained acceptable quality (5.6), outperforming all bermudagrass cultivars and Zeon and JaMur zoysiagrass. In the 80% shade level, Zorro, Palisades, JaMur, and Geo zoysiagrass exhibited the greatest turf quality, significantly greater than that of Tifway, TifGrand and Celebration bermudagrass. Compared to all other bermudagrass cultivars, Latitude 36 had the highest turf quality, significantly greater than that of Tifway and TifGrand. In 90% shade, all zoysiagrass cultivars had significantly greater turf quality than bermudagrass cultivars. Furthermore, quality of every bermudagrass declined substantially, as nearly all canopy cover was lost under this heavy shade. Zoysiagrass cultivars had overall better turf quality than bermudagrass cultivars in 70, 80, and 90% shade treatments.

Within the rough mowing height, there were significant cultivar effects on turf quality for all shade treatments except for full sun (Table 10). In 30% shade, Zorro (6.4) and Palisades (6.3) exhibited the greatest turf quality,significantly greater than that for all bermudagrass cultivars. Also in 30% shade, Tifway turf quality dropped below minimal acceptable turf quality. In 50% shade, Zeon, Zorro, and Palisades zoysiagrass had the greatest turf quality, significantly greater than that for Tifway and TifGrand bermudagrass. In 50% shade, Celebration and Latitude 36 maintained minimally acceptable turf. In 70% shade, Zeon and Palisades zoysiagrass were the only two cultivars to maintain acceptable turf quality, and possessed significantly greater quality than all bermudagrass cultivars. In 80% shade, JaMur had the greatest turf quality, significantly greater than that for all bermudagrass cultivars. In 90% shade, JaMur zoysiagrass had the greatest turf quality at the rough mowing height, significantly greater than that for all bermudagrass cultivars as well as Zeon zoysiagrass and Palmetto St. Augustinegrass.

Table 10. Turf quality of each cultivar and main effect of Primo as affected by shade level for fall 2016. Fairway turf quality data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	5.7	5.0	5.0	4.2	3.6	3.0
TifGrand	6.0	5.7	5.3	4.7	3.9	3.1
Celebration	6.1	5.5	5.4	4.4	4.1	3.0
Latitude 36	6.3	5.7	5.4	4.5	4.5	3.1
Zeon	6.4	5.9	5.5	5.0	4.4	4.0
Zorro	6.3	5.7	5.6	5.5	4.9	4.2
Palisades	6.4	5.9	5.8	5.2	4.6	3.6
JaMur	6.4	5.8	5.6	5.1	4.7	3.9
Geo	6.4	6.1	6.1	5.6	4.7	4.1
LSD	0.6	0.4	0.3	0.4	0.5	0.3
-Primo	6.1	5.5	5.3	4.8	4.3	3.5
+Primo	6.3	5.9	5.7	5.1	4.5	3.6
Cultivar	*	***	***	***	***	***
Primo	*	***	***	***	**	**
Cultivar*Primo	NS	NS	NS	NS	NS	NS
			Rough			
Tifway	5.7	5.4	5.3	4.7	4.3	3.4
TifGrand	5.9	5.5	5.3	5	4.5	3.6
Celebration	5.9	5.6	5.5	5.1	4.8	3.3
Latitude 36	5.9	5.6	5.5	4.8	4.8	3.4
Zeon	6.5	6.2	5.9	5.6	4.9	4.4
Zorro	6.3	6.4	5.8	5.3	5.2	4.5
Palisades	6.4	6.3	5.9	5.5	5.1	4.6
JaMur	6.5	6.2	5.7	5.3	5.3	4.9
Palmetto	6.3	6	5.6	5.4	5	4.2
LSD	1.0	0.6	0.4	0.4	0.5	0.4
Cultivar	NS	***	***	***	***	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Normalized Difference Vegetation Index (NDVI)

Spring 2016

Spring 2016 NDVI data consist of the May rating date. At the fairway mowing height, there were significant cultivar effects on NDVI within full sun, 30, 50, 70, and 80% shade treatments (Table 11). In full sun, Zorro had the greatest NDVI (0.71). Also in full sun, Zorro, Zeon, Palisades, Tifway, and TifGrand all showed significantly greater NDVI compared to Latitude 36. In 30% shade, Zorro and Zeon had the greatest NDVI, significantly greater than that for all bermudagrass cultivars and Geo zoysiagrass. Also, comparing the bermudagrasses in 30% shade, Tifway and TifGrand each had significantly greater NDVI than Celebration and TifGrand. Within 50% shade, Zeon and Zorro had the greatest NDVI levels (~0.67), significantly greater than that for all bermudagrss cultivars and Geo zoysiagrass. In 70% shade, Zorro had an NDVI value of 0.58,significantly greater than that of all bermudagrass cultivars and Palisades and Geo zoysiagrass. In 80% shade, Zorro had the greatest NDVI, significantly greater than that for Geo zoysiagrass and Celebration bermudagrass. In general at the fairway height, Zorro exhibited the greatest NDVI of all cultivars except Geo, and exceeded that of all bermudagrasses at all shade levels.

Rough mowing height generally led to elevated NDVI compared to fairway mowing height. ANOVA revealed significant cultivar effects on NDVI within 30, 50, and 70% shade treatments (Table 11). In full sun, Zeon had the highest NDVI, significantly greater than that of Tifway bermudagrass. In 50% shade, all zoysiagrass cultivars and Palmetto St. Augustinegrass had NDVI of greater than 0.6,significantly greater than that of bermudagrass cultivars. In 70% shade, TifGrand expressed significantly greater NDVI than Tifway. With regard to the zoysiagrass cultivars, Zeon and Zorro NDVI levels (~0.68) exceeded that of all bermudagrass cultivars in 70% shade.

Table 11. NDVI as influenced by cultivar and shade level for spring 2016.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	0.69	0.52	0.48	0.42	0.44	0.37
TifGrand	0.69	0.50	0.46	0.42	0.42	0.43
Celebration	0.64	0.38	0.41	0.35	0.37	0.40
Latitude 36	0.54	0.35	0.37	0.42	0.45	0.41
Zeon	0.70	0.64	0.67	0.51	0.43	0.35
Zorro	0.71	0.72	0.66	0.58	0.52	0.44
Palisades	0.68	0.53	0.53	0.42	0.40	0.38
JaMur	0.65	0.60	0.54	0.50	0.40	0.36
Geo	0.67	0.46	0.42	0.40	0.37	0.33
LSD	0.13	0.11	0.17	0.14	0.12	0.12
Cultivar	*	***	***	**	*	NS
			Rough			
Tifway	0.68	0.50	0.43	0.51	0.50	0.58
TifGrand	0.69	0.67	0.54	0.54	0.51	0.63
Celebration	0.67	0.52	0.49	0.56	0.57	0.62
Latitude 36	0.71	0.56	0.53	0.41	0.49	0.61
Zeon	0.68	0.70	0.68	0.69	0.54	0.61
Zorro	0.70	0.69	0.69	0.67	0.62	0.56
Palisades	0.68	0.62	0.65	0.60	0.51	0.57
JaMur	0.65	0.64	0.65	0.64	0.58	0.57
Palmetto	0.66	0.67	0.66	0.62	0.57	0.58
LSD	0.09	0.19	0.11	0.10	0.13	0.08
Cultivar	NS	*	***	***	NS	NS

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Summer 2016

Summer 2016 data consisted of June, July and August rating dates. Within the fairway mowing height, there were significant cultivar effects on NDVI in full sun, 30, 50, and 90% shade treatments (Table 12). Also, Primo applications significantly increased NDVI in 30, 50, and 70% shade levels. In full sun, TifGrand had the highest NDVI (0.66), significantly higher than that of other bermudagrass cultivars and Zorro and Palisades zoysiagrass. In 30% shade, Zorro and TifGrand had the highest NDVI (~0.64), significantly greater than that for Tifway, Celebration and Latitude 36 bermudagrasses. In 50% shade, JaMur and TifGrand had the highest NDVI, significantly greater than that of Celebration and Zeon. In 70% shade, Palisades zoysiagrass had the highest NDVI (0.58), significantly greater than that for Celebration bermudagrass. In 90% shade, Zorro and JaMur had the highest NDVI, significantly greater than that of Tifway, Celebration and Palisades.

Rough mowing height generally led to elevated NDVI reading at the 70, 80, and 90% shade levels. ANOVA detected significant cultivar effects on NDVI in 30, 50, and 70% shade treatments (Table 12). In 30% shade, Zeon had the highest NDVI (0.61), significantly greater than that of Latitude 36. In 50% shade, Tifgrand bermudagrass and Zorro zoysiagrasshad NDVI of 0.62,significantly higher than that of Tifway and Latitude 36. In the 70% shade level, Palmetto showed the greatest NDVI (0.59), which wassignificantly greater than that for all bermudagrass cultivars. Also in 70% shade, Latitude 36 had the lowest NDVI of all cultivars. In 80% shade, JaMur had the highest NDVI (0.58), significantly greater than that for Celebration bermudagrass. In 90%

shade, JaMur continued to have the highest NDVI (0.52), significantly greater than that for all bermudagrass cultivars, Zeon zoysiagrass, and Palmetto St. Augustinegrass.

Table 12. NDVI as influenced by cultivar, Primo, and shade level for summer 2016. Cultivar NDVI data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	0.58	0.56	0.57	0.53	0.38	0.34
TifGrand	0.66	0.64	0.62	0.54	0.46	0.37
Celebration	0.58	0.53	0.55	0.51	0.42	0.32
Latitude 36	0.56	0.55	0.59	0.53	0.48	0.36
Zeon	0.62	0.58	0.56	0.54	0.44	0.41
Zorro	0.57	0.63	0.60	0.55	0.50	0.43
Palisades	0.57	0.62	0.61	0.58	0.43	0.36
JaMur	0.62	0.61	0.62	0.57	0.45	0.43
Geo	0.63	0.59	0.58	0.55	0.43	0.38
LSD	0.07	0.06	0.05	0.06	0.11	0.06
-Primo	0.60	0.57	0.56	0.52	0.43	0.37
+Primo	0.60	0.61	0.61	0.57	0.56	0.38
Cultivar	**	***	*	NS	NS	***
Primo	NS	***	***	***	NS	NS
Cultivar*Primo	NS	NS	NS	NS	NS	NS
			Rough			
Tifway	0.58	0.56	0.54	0.50	0.50	0.40
TifGrand	0.63	0.60	0.62	0.50	0.50	0.40
Celebration	0.62	0.54	0.59	0.50	0.49	0.33
Latitude 36	0.61	0.53	0.51	0.46	0.50	0.39
Zeon	0.61	0.61	0.58	0.53	0.53	0.40
Zorro	0.56	0.60	0.62	0.54	0.57	0.48
Palisades	0.57	0.60	0.60	0.56	0.56	0.48
JaMur	0.57	0.59	0.61	0.57	0.58	0.52
Palmetto	0.58	0.61	0.6	0.59	0.57	0.42
LSD	0.08	0.08	0.08	0.07	0.09	0.09
Cultivar	NS	*	***	***	*	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Fall 2016

Fall 2016 data consisted of September, October and November rating dates, within the fairway mowing height, there were significant cultivar effects on NDVI across all shade treatments (Table 13). Also, Primo applications significantly increased NDVI in 30, 70, 80, and 90% shade levels. In full sun, Geo and Celebration had the highest NDVI, significantly higher than that of Tifway. In 30% shade, all zoysiagrass cultivars had NDVI of ~0.6, significantly higher than that of Tifway bermudagrass. Also in 30% shade, TifGrand had the highest NDVI (0.63), which was significantly higher than that of Tifway and Latitude 36 bermudagrass. At the 50% shade level, Geo had the highest NDVI (0.68), significantly greater than all bermudagrass cultivars and Zorro zoysiagrass. Among the bermudagrass cultivars in 50 and 70% shade, Latitude 36, Celebration and TifGrand expressed significantly higher NDVI than Tifway. In 70% shade, Zorro and Geo had the highest NDVI (~ 0.6), significantly higher than that of all bermudagrass cultivars and Zeon zoysiagrass. In 80% shade, JaMur zoysiagrass had the highest NDVI (0.52), significantly higher than all bermudagrass cultivars. Latitude 36 and Celebration also had significantly higher NDVI in 80% shade compared to Tifway bermudagrass. In 90% shade, JaMur zoysiagrass maintained the highest NDVI (0.45), significantly higher than that of all bermudagrass cultivars and Palisades zoysiagrass.

Rough mowing height generally led to elevated NDVI compared to fairway mowing height. There were significant cultivar effects on NDVI in 30, 50, 70, 80 and 90% shade treatments (Table 13). In 30% shade, Palisades zoysiagrass had the highest NDVI (0.66), significantly greater than that of Tifway and Zeon. Within the 30, 50, and

70% shade levels, TifGrand, Celebration and Latitude 36 bermudagrasses had significantly greater NDVI than Tifway bermudagrass. In 50% shade, Palisades zoysiagrass had the highest NDVI (0.64), significantly higher than that of Tifway and Latitude 36 bermudagrass. In 70% shade, Palisades and Palmetto had the highest NDVI (0.6), significantly greater than that of Tifway, TifGrand and Latitude 36 bermudagrass. Also in 70% shade, Celebration NDVI was significantly higher than that of Tifway within the bermudagrass cultivars. At the 80% shade level, Palisades maintained the highest NDVI (0.58), significantly greater than that for Tifway, TifGrand and Latitude 36. In 90% shade, Palisades and JaMur had the highest NDVI (0.5), significantly greater than that of all bermudagrass cultivars. In general, zoysiagrass cultivars showed higher NDVI than bermudagrass cultivars in 70, 80, and 90% shade, consistent with their improved turf quality and green cover reported earlier for these heavier shade environments.

Table 13. NDVI as influenced by cultivar, Primo, and shade level for fall 2016. Cultivar NDVI data are pooled across Primo levels.

	Full Sun	**30%**	**50%**	**70%**	**80%**	**90%**
			Fairway			
Tifway	0.57	0.54	0.48	0.42	0.30	0.29
TifGrand	0.62	0.63	0.55	0.49	0.36	0.30
Celebration	0.66	0.58	0.58	0.47	0.40	0.30
Latitude 36	0.64	0.56	0.58	0.49	0.43	0.28
Zeon	0.61	0.60	0.58	0.53	0.47	0.41
Zorro	0.62	0.61	0.58	0.60	0.50	0.44
Palisades	0.64	0.60	0.60	0.56	0.50	0.37
JaMur	0.64	0.60	0.59	0.57	0.52	0.45
Geo	0.66	0.61	0.64	0.59	0.45	0.43
LSD	0.05	0.05	0.05	0.05	0.09	0.07
-Primo	0.63	0.58	0.57	0.5	0.42	0.35
+Primo	0.63	0.61	0.58	0.54	0.46	0.38
Cultivar	***	***	***	***	***	***
Primo	NS	**	NS	***	**	**
Cultivar*Primo	NS	NS	NS	NS	NS	NS
			Rough			
Tifway	0.60	0.56	0.53	0.43	0.41	0.31
TifGrand	0.66	0.64	0.61	0.52	0.46	0.35
Celebration	0.64	0.62	0.62	0.58	0.51	0.33
Latitude 36	0.62	0.63	0.59	0.51	0.49	0.36
Zeon	0.64	0.61	0.61	0.58	0.51	0.46
Zorro	0.62	0.65	0.63	0.58	0.57	0.49
Palisades	0.65	0.66	0.64	0.60	0.58	0.51
JaMur	0.63	0.63	0.63	0.58	0.57	0.50
Palmetto	0.64	0.64	0.62	0.60	0.56	0.44
LSD	0.06	0.04	0.05	0.05	0.08	0.09
Cultivar	NS	***	***	***	***	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Root Dry Mass

Root dry mass was evaluated within full sun and 50% shade treatments for both levels of Primo. ANOVA detected both cultivar and shade level main effects for root dry mass, with shade level showing a more pronounced effect than cultivar, based on the higher F-value (Table 14).

When pooled across shade levels and Primo Celebration bermudagrass exhibited the greatest root dry mass (0.275 g), which was significantly greater than that of JaMur and Geo zoysiagrass (0.154 and 0.161 g, respectively). Within the zoysiagrass cultivars, Palisades (0.266 g) had a significantly greater root dry mass compared to JaMur (0.154 g) (Table 15).

Data were also pooled across cultivar and Primo in order to determine effect of shade level on root dry mass. As such, full Sun plants had root dry mass averaging 0.273 g, significantly greater than that of the 50% Shade Level, which showed root dry mass of 0.167 g (Table 16).

Table 14. ANOVA showing main effects of cultivar, shade level, and Primo for fairway study root dry mass. Root samples (5 cm diameter x 30 cm deep) were removed from plots in October 2016.

Source	df	Mean Square	F	Sig.
Cultivar	8	0.031	2.556	0.014
Shade Level	1	0.400	33.337	0.000
Primo	1	0.15	1.236	0.269
Cultivar x Shade Level	8	0.016	1.316	0.243
Cultivar x Primo	8	0.01	0.868	0.546
Primo x Shade Level	1	0.023	1.895	0.171

Table 15. Cultivar main effect on fairway root dry mass (g). Data have been pooled across shade (0 and 50%) and Primo levels.

Cultivar	Mean
Tifway	0.246
TifGrand	0.233
Celebration	0.275
Latitude 36	0.246
Zeon	0.203
Zorro	0.196
Palisades	0.266
JaMur	0.154
Geo	0.161
LSD	0.108
Cultivar	*

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$

Table 16. Main effect of shade level (0 and 50%) on root dry mass (g) in the fairway mowing height study. Data are pooled across cultivar and Primo levels.

Cultivar	Mean
Full Sun	0.273
50% Shade Level	0.167
LSD	0.051
Shade Level	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Fairway Shear Strength Testing

Based on ANOVA, there were both cultivar and shade level main effects on shear strength, but no significant interactions (Table 17). Furthermore, cultivar and shade level both showed great effect according to the high F-Value.

Data were pooled across shade and Primo levels to determine cultivar effects on shear strength (Table 18). Zeon, Zorro, and Geo all exhibited exceptional shear strength (20.73, 20.05, and 20.25 Nm, respectively). Next, JaMur exhibited good shear strength (19.187 Nm). The aforementioned zoysiagrass cultivars all showed significantly greater shear strength than any bermudagrass cultivars. Among the bermudagrass cultivars, TifGrand showed the highest shear strength (16.36 Nm), which was significantly greater than Tifway (13.72 Nm) (Table 18).

To determine main effect of shade level, data were pooled across cultivar and Primo levels. Full Sun exhibited the greatest shear strength (19.51 Nm), which was significantly greater than 30 and 70% shade levels. Full sun, 30, and 50% shade levels all had similar shear strength (Table 19).

Table 17. ANOVA with cultivar, shade level, and Primo effects on fairway shear strength. Shear strength measurements were taken in October 2016.

Source	df	Mean Square	F	Sig.
Cultivar	8	247.817	17.339	0.000
Shade Level	3	401.052	28.060	0.000
Primo	1	8.855	0.620	0.432
Cultivar x Shade Level	24	13.126	0.918	0.577
Cultivar x Primo	8	10.476	0.733	0.662
Primo x Shade Level	3	4.124	0.289	0.834

Table 18. Main effect of cultivar on fairway shear strength. Data are pooled across shade and Primo levels.

Cultivar	Mean
Tifway	13.72
TifGrand	16.36
Celebration	14.22
Latitude 36	14.92
Zeon	20.73
Zorro	20.05
Palisades	16.08
JaMur	19.19
Geo	20.25
LSD	2.634
Cultivar	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Table 19. Main effect of shade level on turf shear strength. Data are pooled across cultivar and Primo levels.

Cultivar	Mean
Full Sun	19.51
30% Shade Level	16.22
50% Shade Level	18.92
70% Shade Level	14.47
LSD	1.76
Shade Level	***

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS not significant at $P \leq 0.05$.

Minimal Daily Light Integrals (DLI) Requirements

DLI data were converted to monthly averages for each month of the study from October 2015 through December 2016. Spring averages were made up of the months of April, March and May, Summer was made up of June, July and August, Fall was made up of September, October and November, and Winter was made up of December, January and February. Summer had the highest DLI (47.63 mol·m^{-2}·d^{-1}), Spring had the next highest DLI (36.45 mol·m^{-2}·d^{-1}), Fall had a DLI of 32.97 mol·m^{-2}·d^{-1}, and Winter DLI was lowest (26.2 mol·m^{-2}·d^{-1}). Summer and fall data exhibited greater variation compared with spring and fall (Table 20).

Table 20. Daily light integrals (DLI) average +/- standard deviation for 2016, calculated for each season within each shade level. Data were collected every 15 minutes, with daily DLI used as replicate values within each month.

Shade Level	Spring	Summer	Fall	Winter
0	36.45 +/- 2.66	47.63 +/- 6.78	32.97 +/- 7.60	26.20 +/- 2.02
30	20.50 +/- 1.00	27.90 +/- 4.21	18.53 +/- 4.67	14.35 +/- 2.86
50	15.75 +/- 0.35	20.90 +/- 2.80	14.47 +/- 3.63	11.05 +/- 2.76
70	8.96 +/- 0.35	11.70 +/- 1.66	7.93 +/- 2.10	5.80 +/- 1.51
80	6.25 +/- 0.45	8.60 +/- 1.42	5.40 +/- 1.42	3.80 +/- 0.80
90	4.35 +/- 0.15	5.80 +/- 0.92	3.53 +/- 1.08	2.45 +/- 0.65

Non-linear regression was performed using turf quality and DLI data for each season during 2016 (2015 fall data were omitted from this analysis due to the limited amount of time shade structures had been in place). Data are presented by mowing height study (fairway or rough) as well as by Primo level within each season (spring, summer, and fall). The quadratic equation provided the best fit for the majority of cases evaluated.

Fairway Daily Light Integral (DLI) Requirements

Based on regression analysis of fairway mowing height (without trinexapac-ethyl) for spring, Zeon had the lowest DLI requirement for acceptable quality (8.6 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Zorro (11.5 $mol \cdot m^{-2} \cdot d^{-1}$), Palisades (16.2 $mol \cdot m^{-2} \cdot d^{-1}$), JaMur (19.3 $mol \cdot m^{-2} \cdot d^{-1}$), and Geo (20.0 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 21; Figure 5). Within the bermudagrasses, TifGrand had the lowest DLI requirement in spring (26.8 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Celebration (32.7 $mol \cdot m^{-2} \cdot d^{-1}$), Latitude 36 (33.1 $mol \cdot m^{-2} \cdot d^{-1}$), and Tifway (34 $mol \cdot m^{-2} \cdot d^{-1}$), which had the highest spring DLI requirement for fairway height turf.

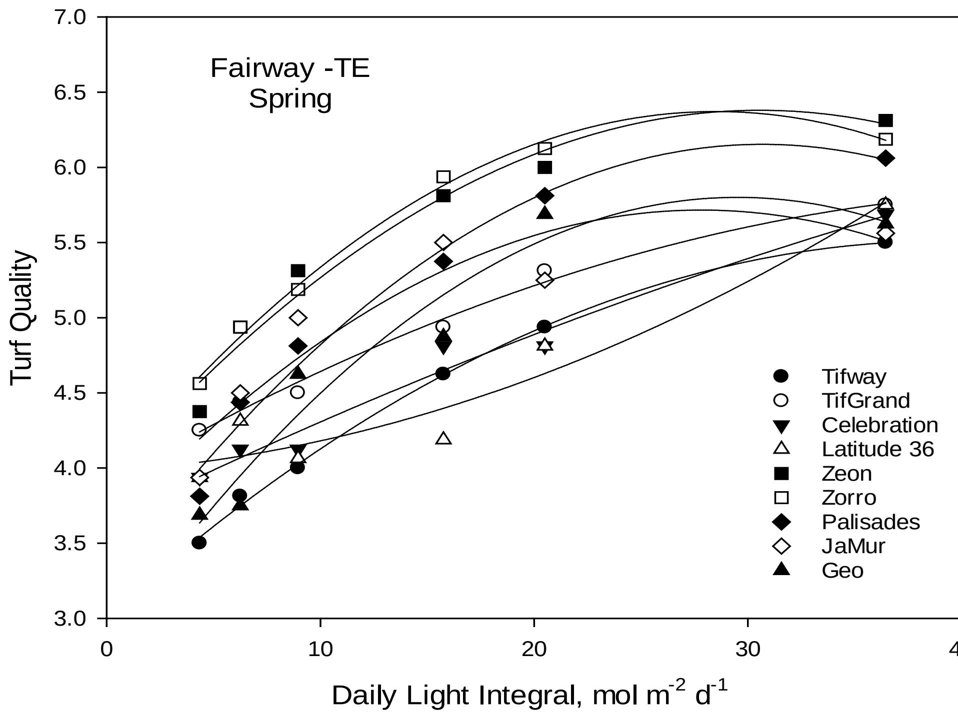

Figure 5. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for fairway turf in spring without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 21. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 21. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on fairway turf in spring without TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0016x2 + 0.1275x + 3.0154	0.9977	0.0001	33.95737471
TifGrand	y = -0.0009x2 + 0.0841x + 3.8917	0.9898	0.001	26.82332653
Celebration	y = -0.0004x2 + 0.0697x + 3.6476	0.9752	0.0039	32.72127196
Latitude 36	y = 0.0011x2 + 0.0096x + 3.9758	0.9348	0.0166	33.11539359
Zeon	y = 0.0026x2 + 0.1610x + 3.9205	0.965	0.0066	8.612655957
Zorro	y = -0.0030x2 + 0.1723x + 3.9154	0.9945	0.0004	11.49903197
Palisades	y = -0.0031x2 + 0.1911x + 3.2218	0.9788	0.0031	16.15532965
JaMur	y = -0.0028x2 + 0.1537x + 3.5779	0.8592	0.0528	19.27072337
Geo	y = -0.0034x2 + 0.2018x + 2.8216	0.942	0.014	20.03654317

For fairway turf in summer months without TE, Zorro had the lowest minimal DLI requirement (19.8 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Palisades (20.2 $mol \cdot m^{-2} \cdot d^{-1}$), Zeon (20.3 $mol \cdot m^{-2} \cdot d^{-1}$), Geo (21.7 $mol \cdot m^{-2} \cdot d^{-1}$), and JaMur (21.7 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 22; Figure 6). Within the bermudagrasses, Latitude 36 was found to have the lowest DLI requirement (24.7 $mol \cdot m^{-2} \cdot d^{-1}$), followed by TifGrand (25 $mol \cdot m^{-2} \cdot d^{-1}$), Celebration (25 $mol \cdot m^{-2} \cdot d^{-1}$), and then Tifway (25.7 $mol \cdot m^{-2} \cdot d^{-1}$), which hadad the highest minimal DLI requirement of all cultivars during summer.

For fairway turf in summer with TE applied, Zorro had the lowest minimal DLI requirement (15.8 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Palisades (16.2 $mol \cdot m^{-2} \cdot d^{-1}$), JaMur (16.5 $mol \cdot m^{-2} \cdot d^{-1}$), Zeon (17.7 $mol \cdot m^{-2} \cdot d^{-1}$), and Geo (18.9 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 23; Figure 7). Within the bermudagrasses, TifGrand had the lowest DLI requirement for summer (21.7 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Latitude 36 (22.1 $mol \cdot m^{-2} \cdot d^{-1}$), Celebration (24.6 $mol \cdot m^{-2} \cdot d^{-1}$), and Tifway, which once again had the highest minimal DLI requirement (25.3 $mol \cdot m^{-2} \cdot d^{-1}$).

Based on these data, TE application during summer months led to reduced minimal DLI requirements, particularly for cultivars Zorro, Palisades, and JaMur (Figure 6; Figure 7).

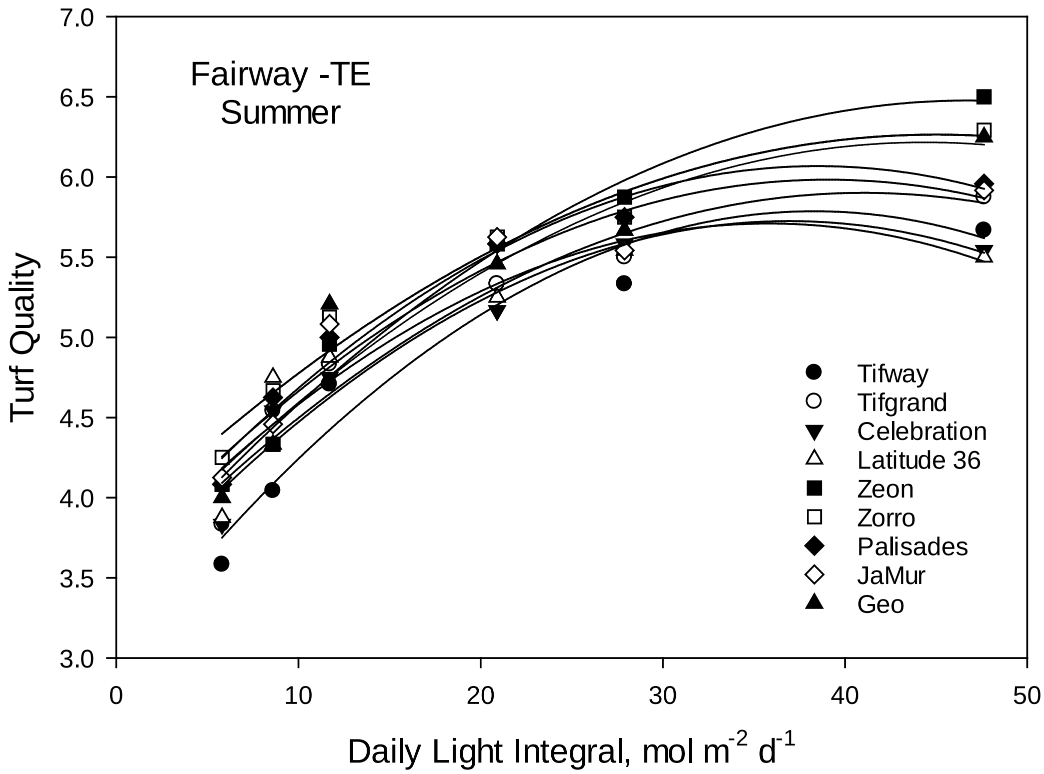

Figure 6. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for fairway turf in summer without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 22. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 22. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on fairway turf in summer without TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0019x2 + 0.1477x + 2.9598	0.9436	0.0134	25.68484086
TifGrand	y = -0.0015x2 + 0.1196x + 3.4486	0.9427	0.0137	24.97535674
Celebration	y = -0.0017x2 + 0.1277x + 3.3696	0.9475	0.0120	25.00937118
Latitude 36	y = -0.0017x2 + 0.1213x + 3.5406	0.8887	0.0371	24.71187674
Zeon	y = -0.0014x2 + 0.1311x + 3.4167	0.9846	0.0019	20.28513747
Zorro	y = -0.0012x2 + 0.1093x + 3.8073	0.9660	0.0063	19.78394803
Palisades	y = -0.0017x2 + 0.1311x + 3.5462	0.9711	0.0049	20.18795653
JaMur	y = -0.0016x2 + 0.1221x + 3.6028	0.9268	0.0198	21.72002738
Geo	y = -0.0014x2 + 0.1219x + 3.5168	0.9190	0.0230	21.65451254

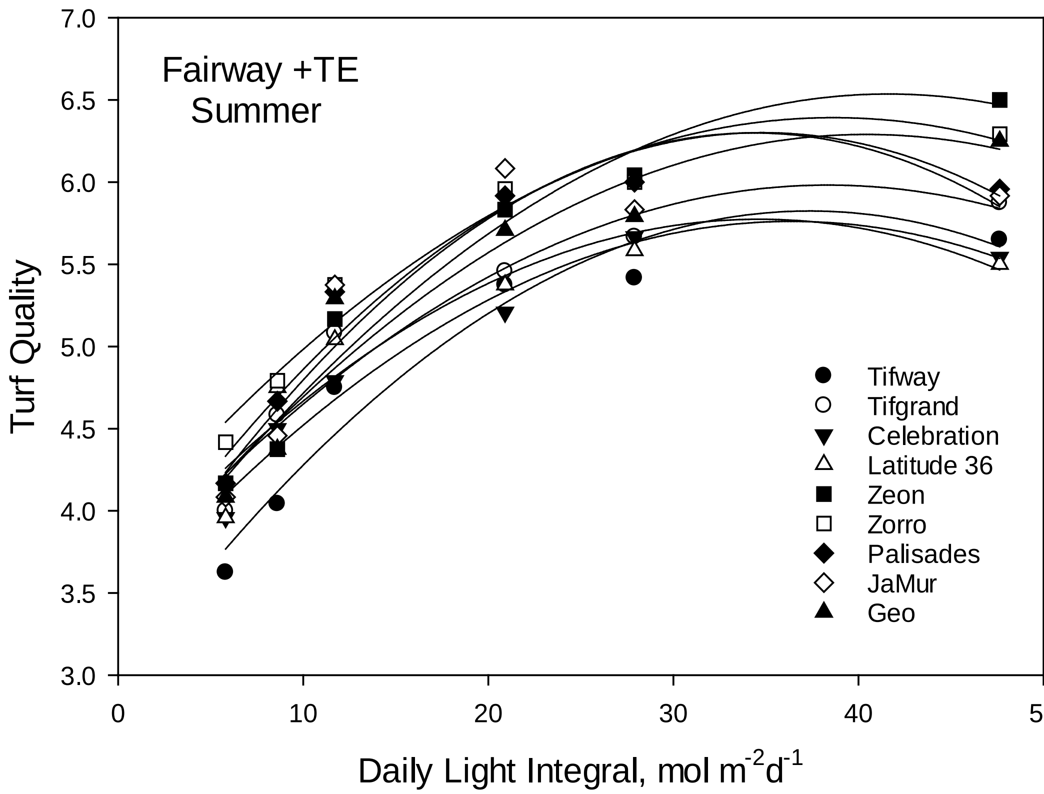

Figure 7. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for fairway turf in summer with TE (+TE). Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 23. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 23. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on fairway turf in summer with TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0021x2 + 0.1543x + 2.9416	0.9496	0.0113	25.27502726
TifGrand	y = -0.0017x2 + 0.1271x + 3.5451	0.9396	0.0148	21.65024771
Celebration	y = -0.0018x2 + 0.1295x + 3.4052	0.9709	0.0050	24.56069323
Latitude 36	y = -0.0018x2 + 0.1263x + 3.5886	0.8920	0.0355	22.08520313
Zeon	y = -0.0018x2 + 0.1516x + 3.3835	0.9706	0.0050	17.66704546
Zorro	y = -0.0017x2 + 0.1328x + 3.8282	0.9565	0.0091	15.77406605
Palisades	y = -0.0023x2 + 0.1629x + 3.4678	0.9498	0.0112	16.16418816
JaMur	y = -0.0025x2 + 0.1742x + 3.3095	0.8898	0.0366	16.46540885
Geo	y = -0.0017x2 + 0.1395x + 3.4739	0.9207	0.0223	18.85760308

For fairway mowing height turf without TE during fall, Geo had the lowest minimal DLI requirement (11.9 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Palisades (13.9 $mol \cdot m^{-2} \cdot d^{-1}$), Zeon (15.2 $mol \cdot m^{-2} \cdot d^{-1}$), JaMur (15.4 $mol \cdot m^{-2} \cdot d^{-1}$), and Zorro (16.4 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 24; Figure 8). Among the bermudagrasses, TifGrand required the lowest DLI for minimal acceptable quality (16.5 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Latitude 36 (16.7 $mol \cdot m^{-2} \cdot d^{-1}$), Celebration (17.9 $mol \cdot m^{-2} \cdot d^{-1}$), and Tifway (23.4 $mol \cdot m^{-2} \cdot d^{-1}$), which again had the highest fall DLI requirement of any cultivar.

For fairway height turf with TE in fall, Geo had the lowest DLI requirement (8.7 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Zorro (10.1 $mol \cdot m^{-2} \cdot d^{-1}$), Palisades (10.8 $mol \cdot m^{-2} \cdot d^{-1}$), JaMur (11.1 $mol \cdot m^{-2} \cdot d^{-1}$), and Zeon (12.2 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 25; Figure 9). Within the bermudagrasses, TifGrand had the lowest minimal DLI (14.0 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Latitude 36 (14.2 $mol \cdot m^{-2} \cdot d^{-1}$), Celebration (14.9 $mol \cdot m^{-2} \cdot d^{-1}$), and Tifway (19.8 $mol \cdot m^{-2} \cdot d^{-1}$), which again had the highest minimal DLI requirement during fall when TE was applied.

As occurred in summer, all cultivars exhibited lower minimal DLI requirements with TE application. Zorro zoysiagrass showed the greatest improvement relative to other cultivars.

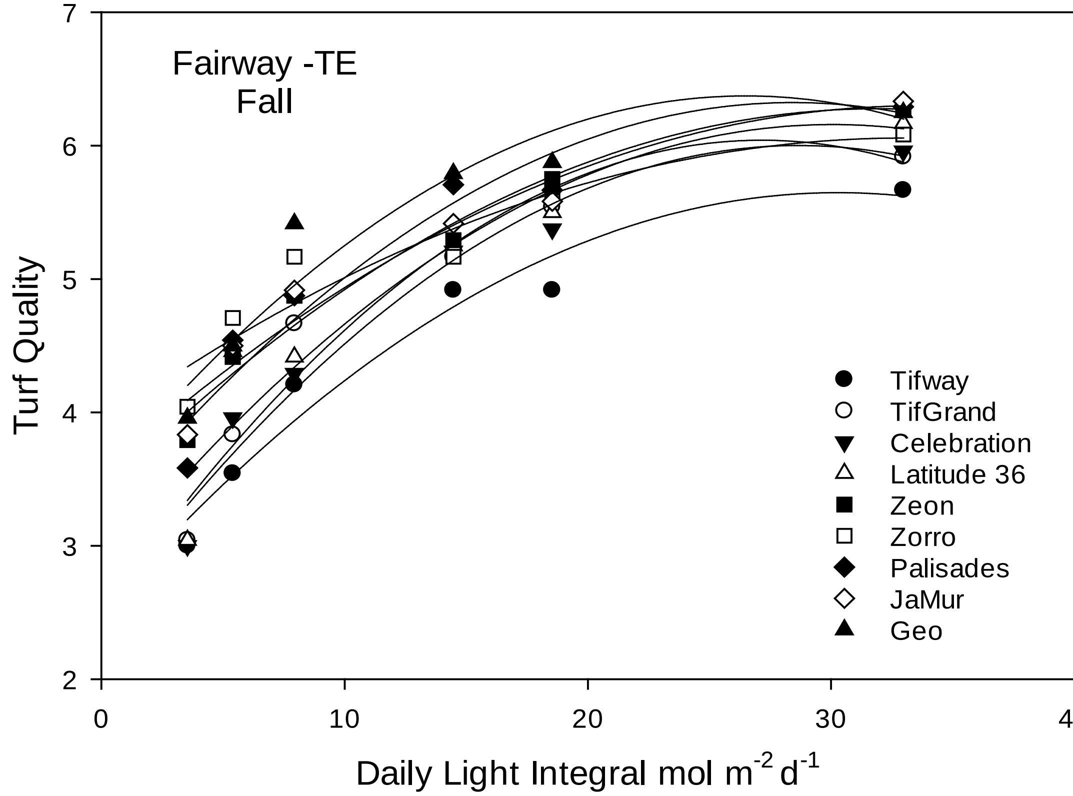

Figure 8. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for fairway turf in fall without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 24. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 24. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on fairway turf in fall without TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0034x2 + 0.2076x + 2.5059	0.9596	0.0081	23.35812627
TifGrand	y = -0.0048x2 + 0.2629x + 2.4726	0.9497	0.0113	16.46512763
Celebration	y = -0.0043x2 + 0.2449x + 2.4934	0.9623	0.0073	17.90718142
Latitude 36	y = -0.0037x2 + 0.2235x + 2.8016	0.8987	0.0322	16.67842996
Zeon	y = -0.0028x2 + 0.1803x + 3.4024	0.9694	0.0054	15.24157217
Zorro	y = -0.0020x2 + 0.1300x + 3.9087	0.8875	0.0377	16.35689001
Palisades	y = -0.0039x2 + 0.2198x + 3.2010	0.9329	0.0174	13.87577024
JaMur	y = -0.0024x2 + 0.1642x + 3.5404	0.9569	0.0090	15.40115201
Geo	y = -0.0041x2 + 0.2182x + 3.4839	0.9150	0.0248	11.90100318

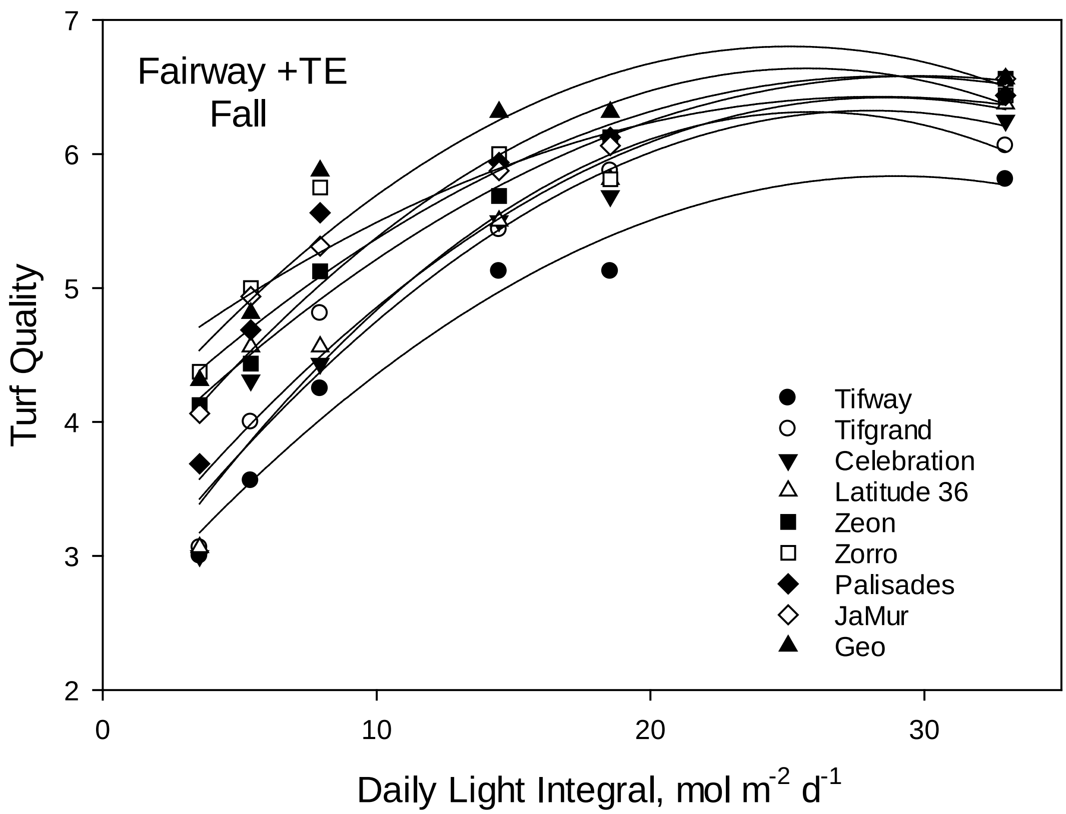

Figure 9. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for fairway turf in fall with TE (+TE). Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 25. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 25. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on fairway turf in fall with TE

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0041x2 + 0.2385x + 2.3837	0.9684	0.0056	19.81793168
TifGrand	y = -0.0058x2 + 0.3028x + 2.3939	0.9551	0.0095	14.02638203
Celebration	y = -0.0048x2 + 0.2705x + 2.5311	0.9361	0.0161	14.93219029
Latitude 36	y = -0.0045x2 + 0.2597x + 2.7155	0.9095	0.0272	14.2314211
Zeon	y = -0.0035x2 + 0.2077x + 3.4881	0.9874	0.0014	12.19100804
Zorro	y = -0.0028x2 + 0.1585x + 4.1880	0.8251	0.0731	10.06842056
Palisades	y = -0.0051x2 + 0.2629x + 3.2616	0.8925	0.0353	10.76040328
JaMur	y = -0.0035x2 + 0.1987x + 3.7298	0.9401	0.0147	11.06586016
Geo	y = -0.0049x2 + 0.2447x + 3.7367	0.9047	0.0294	8.73321881

Rough Height Daily Light Integral (DLI) Requirements

For rough mowing height during spring months, Zeon had the lowest minimal DLI requirement (2.1 mol·m^{-2}·d^{-1}), followed by Zorro (4.3 mol·m^{-2}·d^{-1}), and JaMur (5.1 mol·m^{-2}·d^{-1}) (Table 26; Figure 10). Celebration had the lowest minimal DLI requirement of all bermudagrasses, one zoysiagrass, and St. Augustinegrass (5.7 mol·m^{-2}·d^{-1}), lower than Palisades (8.3 mol·m^{-2}·d^{-1}), Latitude 36 (8.7 mol·m^{-2}·d^{-1}) Palmetto St. Augustinegrass(8.8 mol·m^{-2}·d^{-1}), TifGrand (15.4 mol·m^{-2}·d^{-1}), and Tifway bermudagrass (28.0 mol·m^{-2}·d^{-1}).

Based on these results, mowing height had an obvious effect on minimal DLI requirements during spring, when comparing between fairway and rough studies in spring. Celebration and Latitude 36 showed the greatest reduction of DLI, with an approximately 26 mol·m^{-2}·d^{-1} reduction due to the increased mowing height (Figure 5; Figure 10).

For the rough mowing height during summer, Zorro zoysiagrass had the lowest minimal DLI requirement (14.2 mol·m^{-2}·d^{-1}), followed by Zeon (16.3 mol·m^{-2}·d^{-1}), Palmetto St. Augustinegrass (16.3 mol·m^{-2}·d^{-1}), JaMur zoyisagrass (18.5 mol·m^{-2}·d^{-1}), and Palisades zoysiagrass (18.8 mol·m^{-2}·d^{-1}) (Table 27; Figure 11). Among the bermudagrasses, Celebration had the lowest summer rough DLI (23.0 mol·m^{-2}·d^{-1}) followed by Tifway (25.0 mol·m^{-2}·d^{-1}), Latitude 36 (28.3 mol·m^{-2}·d^{-1}), and TifGrand (30.0 mol·m^{-2}·d^{-1}), which was found to have the highest minimal DLI requirement in summer at rough height.

Once again, cultivars maintained at the rough mowing height generally had a lower minimal DLI requirement than the same cultivars maintained at fairway height during the fall months. Zeon and Zorro appeared to show the greatest improvement with an approximately 4 $mol \cdot m^{-2} \cdot d^{-1}$ reduction in minimal DLI requirements due to increased mowing height in summer (Figure 6; Figure 11).

For the rough mowing height during fall Palisades required the lowest DLI for acceptable quality (9.2 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Zorro (9.7 $mol \cdot m^{-2} \cdot d^{-1}$), JaMur (9.7 $mol \cdot m^{-2} \cdot d^{-1}$), Zeon (9.9 $mol \cdot m^{-2} \cdot d^{-1}$), and Geo (11.3 $mol \cdot m^{-2} \cdot d^{-1}$) (Table 28; Figure 12). Among the bermudagrasses, Celebration had the lowest DLI requirement (13.8 $mol \cdot m^{-2} \cdot d^{-1}$), followed by Latitude 36 (14.6 $mol \cdot m^{-2} \cdot d^{-1}$), TifGrand (15.8 $mol \cdot m^{-2} \cdot d^{-1}$), and Tifway (17.3 $mol \cdot m^{-2} \cdot d^{-1}$), which had the highest minimal DLI requirement of all cultivars during fall. Palmetto had the moderate minimal DLI requirement for 11.3 $mol \cdot m^{-2} \cdot d^{-1}$.

Comparing fairway and rough mowing heights during fall, rough mowing height again led to lower minimal DLI requirements compared to fairway mowing heights. Zeon, Zorro, Palisades and JaMur zoysiagrass appeared to show the greatest reduction in DLI (5 $mol \cdot m^{-2} \cdot d^{-1}$) due to increased mowing height (Figure 8; Figure 12). Furthermore, cultivar DLI requirements were lower in fall and spring compared to summer.

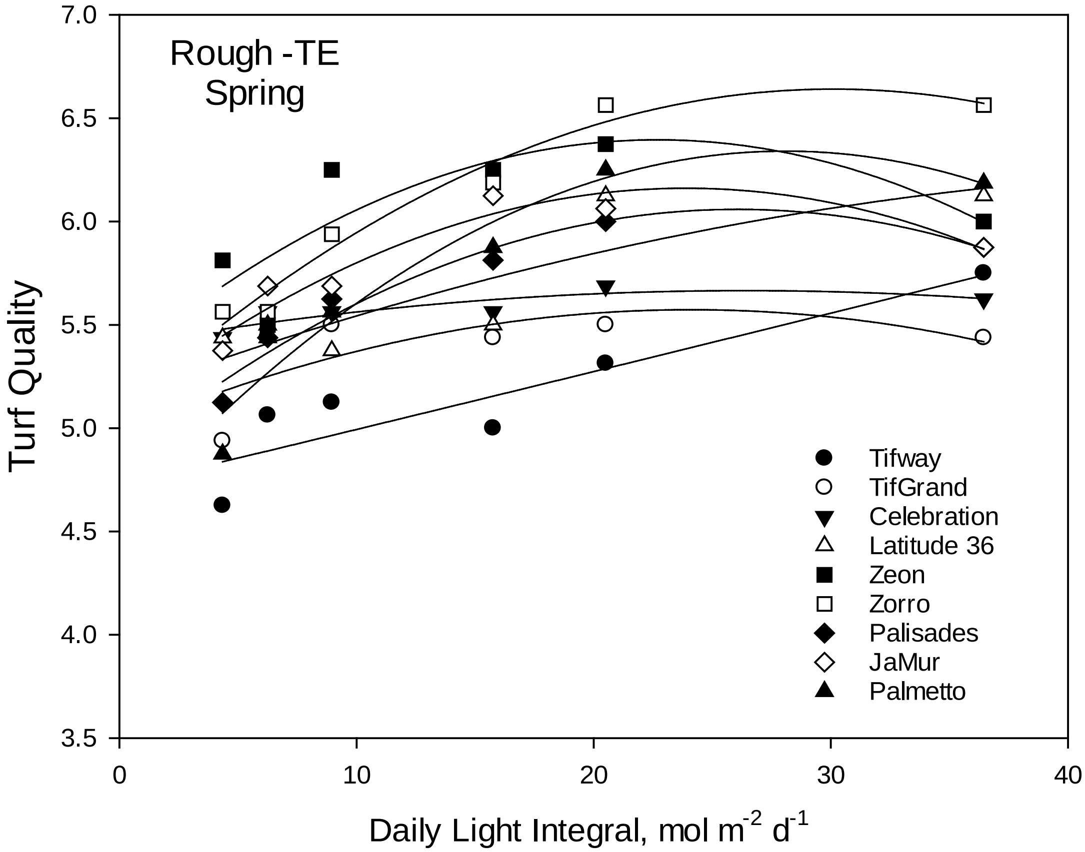

Figure 10. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for rough turf in spring without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 26. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 26. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on rough turf in spring without TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = 1.3706E-005x2 + 0.0276x + 4.7170	0.8192	0.0769	27.98093555
TifGrand	y = -0.0010x2 + 0.0488x + 4.9852	0.4604	0.3964	15.42447773
Celebration	y = -0.0004x2 + 0.0202x + 5.3985	0.7246	0.1445	5.658866802
Latitude 36	y = -0.0004x2 + 0.0426x + 5.1593	0.7610	0.11690	8.709989897
Zeon	y = -0.0021x2 + 0.0956x + 5.3109	0.6557	0.2020	2.07237385
Zorro	y = -0.0017x2 + 0.1034x + 5.0840	0.9665	0.0061	4.331704312
Palisades	y = -0.0018x2 + 0.0921x + 4.8585	0.9503	0.0111	8.317237783
JaMur	y = -0.0019x2 + 0.0894x + 5.0940	0.9125	0.0259	5.09256077
Palmetto	y = -0.0023x2 + 0.1265x + 4.5653	0.9145	0.0250	8.795489965

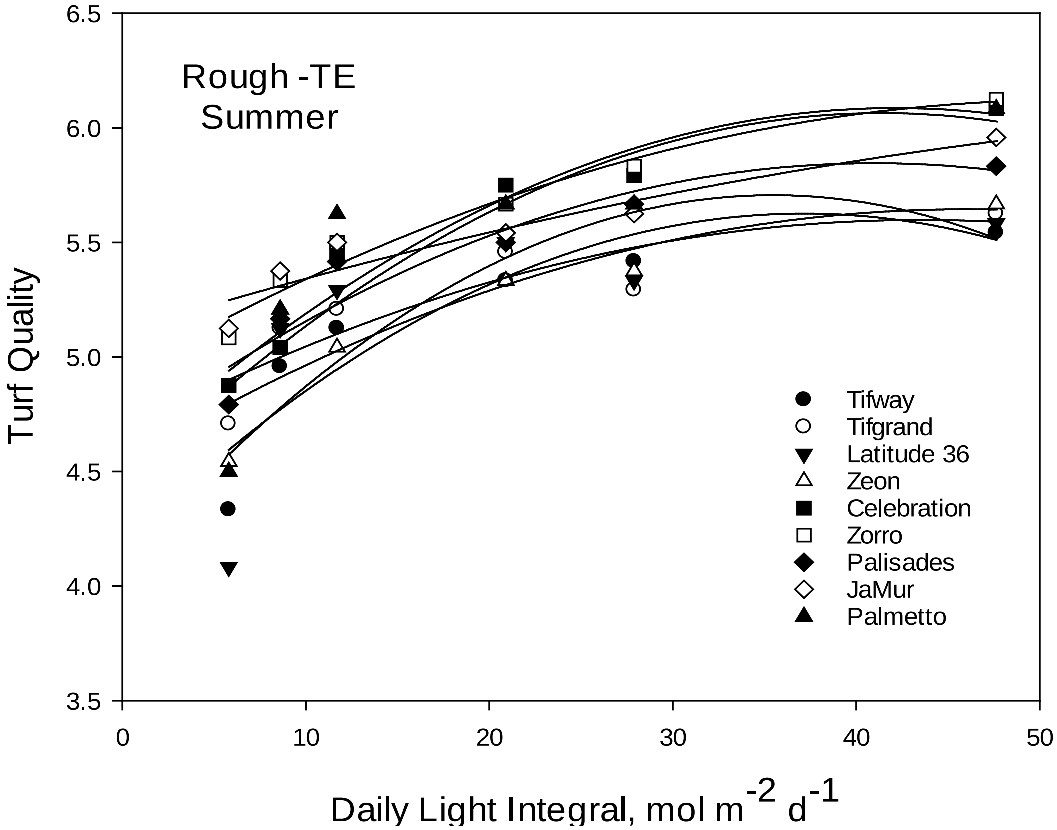

Figure 11. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for rough turf in summer without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 27. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 27. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on rough turf in summer without TE.

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0010x2 + 0.0779x + 4.1781	0.8423	0.0626	24.97851117
TifGrand	y = -0.0005x2 + 0.0427x + 4.6689	0.7736	0.1077	30.00787646
Celebration	y = -0.0013x2 + 0.0912x + 4.0893	0.6286	0.2263	23.02550464
Latitude 36	y = -0.0005x2 + 0.0483x + 4.5342	0.7736	0.1077	28.26777596
Zeon	y = -0.0009x2 + 0.0732x + 4.5456	0.9474	0.0121	16.30823212
Zorro	y = -0.0004x2 + 0.0463x + 4.9225	0.9676	0.0058	14.21992441
Palisades	y = -0.0007x2 + 0.0589x + 4.6404	0.8928	0.0351	18.79042554
JaMur	y = -0.0002x2 + 0.0248x + 5.1102	0.9008	0.0312	18.46840228
Palmeto	y = -0.0009x2 + 0.0780x + 4.4516	0.7515	0.1239	16.63335414

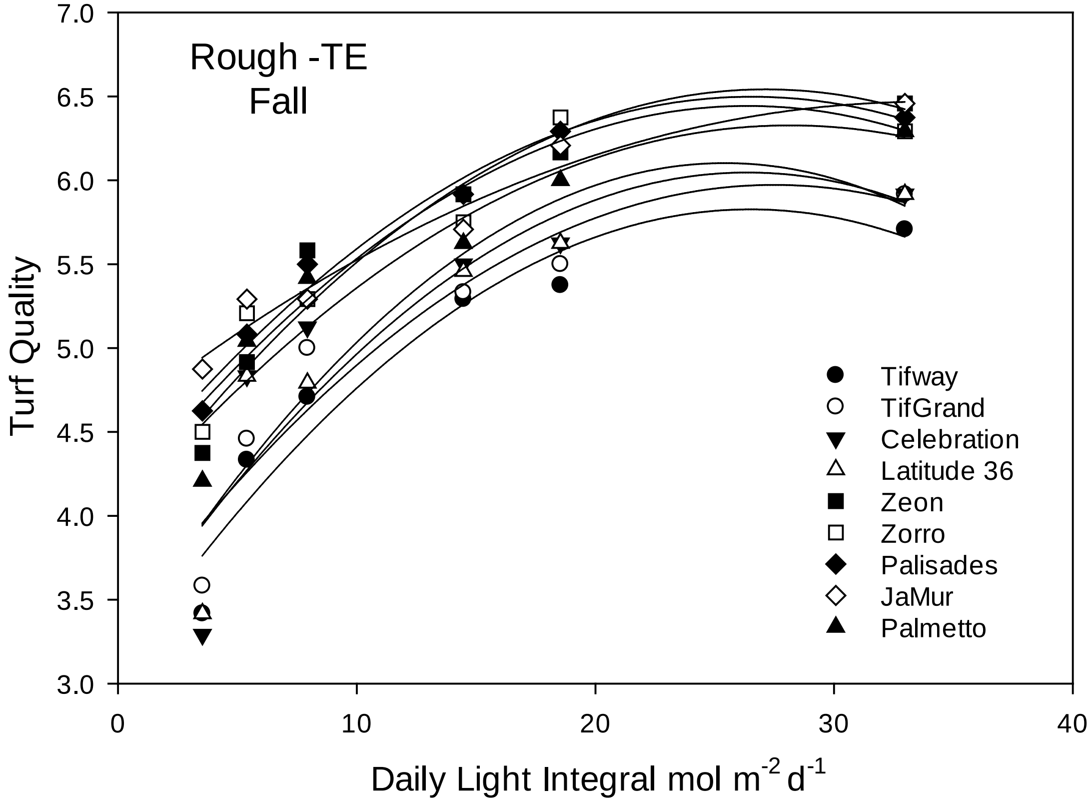

Figure 12. Regression analysis determining the minimum daily light integral (x) requirement for acceptable turfgrass quality (y = 5.5) for rough turf in fall without TE. Regressions were formed for each cultivar using the mean seasonal DLI values presented in Table 28. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar are presented.

Table 28. Regression equations, coefficients of determination (R^2), P-values, and the calculated minimum DLI for each cultivar on rough turf in fall without TE

Cultivar	Regression equation	R^2	P-Value	DLI (mol $m^{-2}d^{-1}$)
Tifway	y = -0.0039x2 + 0.2074x + 3.0794	0.9212	0.0221	17.29739203
TifGrand	y = -0.0035x2 + 0.1930x + 3.3209	0.8977	0.0327	15.84182187
Celebration	y = -0.0045x2 + 0.2283x + 3.2018	0.7851	0.0996	13.84465874
Latitude 36	y = -0.0040x2 + 0.2128x + 3.2413	0.8416	0.0631	14.64654862
Zeon	y = -0.0035x2 + 0.1903x + 3.9608	0.9434	0.0135	9.885667099
Zorro	y = -0.0034x2 + 0.1790x + 4.0843	0.9370	0.0158	9.693861714
Palisades	y = -0.0033x2 + 0.1756x + 4.1682	0.9789	0.0031	9.161671726
JaMur	y = -0.0017x2 + 0.1124x + 4.5697	0.9607	0.0078	9.699660038
Palmetto	y = -0.0029x2 + 0.1656x + 3.9992	0.8975	0.0328	11.29821117

Discussion

Temperature Effects in Shade

Temperature is a key critical factor affecting turfgrass growth and development, and may therefore interact to influence turf quality in the shade environment. For warm-season turfgrasses, the optimum reported temperature range is 26.6 to 35 degrees C (DiPaola and Beard, 1992). Our temperature data showed the density neutral black fabric we used for the shade treatments in this study generally had a cooling effect on soil and air temperatures, relative to full sun conditions. Furthermore, soil temperature appeared to be more stable between treatments compared with air temperature. Minimum monthly soil and air temperatures were also always lowest in full sun plots, likely due to greater nighttime radiational cooling in these uncovered plots. Daytime maximum soil temperature highs exceeding 35 °C also regularly occurred during the summer months in this study, and were considerably higher than those noted for spring and fall. Interestingly, in this study cultivars generally expressed higher turf quality, percent green cover, NDVI, and lower minimal DLI requirements in during spring and fall compared to summer. This observation is consistent with previous research reporting that excessively high temperatures can lead to decrease in photosynthesis and increase in respiration and photorespiration which hinder the grass growth, even in warm-season turf (Baker and Jung, 1968; Watschke et al.1970; Dipaola and Beard, 1992). Furthermore, elevated levels of solar radiation and high evaporative demand during summer can contribute to chlorophyll degradation and physiological stress in warm-season turf, even under well-watered conditions (Bell, 2011). This too likely contributed to decline in summer turf performance for many of these cultivars. These results are also supported by the findings of McBee and Holt (1966), who reported that Tifway bermudagrass, 'Meyer' zoysiagrass and common St. Augustinegrass all exhibited improved density and ground cover in October, compared to summer months.

Species & Cultivar Turf Canopy Cover Responses

In this study, zoysiagrass cultivars generally had improved green cover compared to bermudagrass cultivars (especially Tifway), both under fairway and rough mowing heights as shade levels approached and exceeded 30% levels. These results are therefore in agreement with Trappe et al. (2011), who reported that Zorro and Palisades zoysiagrass maintained improved percent green cover compared to Tifway at a 1.3 cm mowing height in 50% shade, in a field study conducted in Fayetteville, Arkansas.

Interestingly, very few significant differences in green cover were detected among the zoysiagrass cultivars throughout much of the study. The exception to this was Spring 2016, during which time Geo exhibited similarly low percent green cover levels to those of bermudagrass cultivars at both fairway and rough mowing heights. These findings are consistent to those of Zhang et al. (2016) who reported that no differences in percent green cover were found between zoysiagras cultivars JaMur and Zorro in both full sun and 63% shade conditions. The lower spring green cover in Geo could be due to a genetic predisposition toward delayed spring green-up relative to other cultivars and/or decreased tolerance to low winter temperatures. Despite its delayed start during Spring, Geo was able to maintain close to 50% green cover in as heavy as 80% shade levels into Fall of 2015 and 2016. Conversely, Zeon, Zorro, and Palisades each started to decrease to below 50% green cover as shade levels exceeded 50% throughout the whole study.

Considering bermudagrass cultivar responses to shade, TifGrand and Celebration have been reported to possess relatively good shade tolerance relative to other cultivars, yet little information is available for the relatively new Latitude 36 (Baldwin et al., 2007). In this study, few differences were detected throughout the study between TifGrand, Celebration, and Latitude 36 for both mowing heights, and all generally exceeded Tifway in terms of percent green cover. For example, during Fall 2016 at the fairway mowing height, TifGrand, Celebration and Latitude 36 all had significantly greater percent green cover than Tifway in all shade levels except 90% shade. Tifway decreased below 50 percent green cover before it reached the 30% shade level throughout the whole study. The shade-tolerant check Palmetto St. Augustinegrass, maintained equal to or greater than 80% percent green cover in up to 80% shade during Fall 2015, 52% in Spring 2016, 46% in Summer 2016, and 70% in Fall 2016. These data are in agreement with the findings of Wherley et al. (2013) who reported that Palmetto had 49% green cover after 10 weeks in 85% shade in a Summer greenhouse study.

In this study, responses to shade differed considerably between rough and fairway mowing heights. As such, rough mowing height led to greater percent green cover compared to fairway mowing height for both zoysiagrass and bermudagrass cultivars under all shade levels except full sun. This result is consistent with the findings of Bunnell et al. (2005a) who reported that reducing cutting height from 25 to 16 mm significantly decreased turf quality of Tifway, Celebration and Tifsport bermudagrass in South Carolina under 71% shade levels. These findings are also in agreement with those of Bunnell (2005b) who reported that TifEagle Bermudagraass exhibited improved turfgrass quality when maintained at 4.7 compared to 3.2 mm in a separate South Carolina study.

Monthly trinexapac-ethyl applications to fairway mowing height turf during summer and fall 2016 also significantly improved percent green cover in all but full sun and 90% shade levels. This could be explained by more compact growth habit and increased tillering in response to TE applications. Ervin et al. (2002) reported that TE applications (at a rate of 96 g ai ha^{-1} resulted in 97 and 827% more tillers per unit area for ‘Meyer’ zoysiagrass when grown under 77 and 89% shade levels, respectively. Our findings also agree with results of Bunnell et al. (2005b), who reported that ‘TifEagle’ Bermudagrass turf quality was significantly improved with TE application in shaded conditions. The authors reported that hours of sunlight needed for acceptable TifEagle quality were reduced from 8 to 4 hours per day when comparing untreated and TE-treated plants. .

Turf Quality

Turf quality and percent green cover results were generally in agreement during the study. Zoysiagrass cultivars generally had greater turf quality than bermudagrass cultivars at and above 30% shade at both mowing heights. These findings agree with Trappe et al. (2011) who reported that Zorro and Palisades zoysiagrass each had greater percent green cover than Tifway at a 1.3 cm mowing height in 50% shade. They also agree with findings of Bunnell et al. (2005a) who reported that ‘Meyer’ Zoysiagrass had better turf quality than Celebration and Tifway in 41, 58 and 71% shade environments at a 16 mm mowing height, as well as in 58 and 71% shade at a 25 mm mowing height.

Similar to percent green cover results, no differences were observed in turf quality among the zoysiagrass cultivars during summer or fall, regardless of mowing height, and Geo exhibited poor spring turf quality. Within the bermudagrasses, TifGrand, Celebration, and Latitude 36 did not differ during fall 2016, andbegan to drop below acceptable quality levels at shade levels at or above 50%. Similar to green cover results, Geo exhibited greater turf quality than other zoysiagrass cultivars during fall, maintaining acceptible quality in up to 80% shade during fall 2015 and into 70% shade during Fall 2016.

Within fairway mowing height plots in fall 2015 (the first season shade structures were placed over the turf) shade stress was not immediately apparent in plots, as all cultivars maintained acceptable turf quality into 80% shade, except for Tifway bermudagrass, which dropped to below acceptable quality at shade levels of 30% or more. These observations are consistent with those of Bunnell et al. (2005a), who reported that Celebration maintained acceptable turf quality into 71% shade, whereas Tifway fell below acceptable quality in as little as 41% shade. This also agrees with findings from a greenhouse study conducted by Zhang et al. (2016), who reported that Geo, JaMur, and Palisades maintained above-acceptable quality at 61% shade levels, but that However, the authors also found that Zeon and Zorro fell to below minimal acceptable turf quality under 61% shade levels, which is contradictory to our findings.

By the 2016 season, zoysiagrass cultivars began to fall below acceptable quality at shade levels above 50%, while bermudagasses fell below acceptable quality beyond 30% shade levels. As such, our results differ from those of Bunnell et al (2005a) and Zhang et al. (2016). One major factor that likely contributed to lower observed performance in our study was that shade structures in our study remained on the turf over the entire duration of the study (even over winter dormancy), whereas many of the aforementioned studies were short-term (3 months or less) in nature.

As with percent green cover responses, cutting height also noticeably improved turf quality, when comparing studies. Rough mowing heights led to greater turf quality in both zoysiagrass and bermudagrass cultivars in all shade treatments. In 2016, all bermudagrass cultivars except Tifway maintained acceptable quality up until 50% shade levels, and zoysiagrass maintained acceptable quality up until 70% shade. These results are also similar to findings of Bunnell et al. (2005a) who reported that reducing cutting height from 25 to 16 mm significantly decreased turf quality of Tifway, Celebration, and Tifsport bermudagrass under 71% shade. They also also agree with those of Bunnell (2005b), who reported that TifEagle Bermudagraass exhibited improved turfgrass quality when maintained at 4.7 compared to 3.2 mm mowing height.

Trinexapac-ethyl application also significantly improved summer and fall turf quality in moderate shade. TE application improved turf quality from 5.4 to 5.7, and from 5.3 to 5.7 in 50% shade in summer and fall 2016, respectively. These data agree with those of Ervin et al. (2002), who reported that the TE application resulted in significant turf quality improvement for Meyer zoysiagrass in 77% shade. It also agrees with Bunnell et al. (2005b), who found improved quality of ‘TifEagle’ Bermudagrass with TE application.

NDVI Responses

At the fairway mowing height, Tifway had an NDVI in 70% shade of 0.42 in spring 2016, 0.53 in summer 2016, and 0.42 during fall 2016. In comparison, TifGrand had an NDVI in 70% shade of 0.42 in spring 2016, 0.54 in summer 2016, and 0.49 during fall 2016. The results are similar to Aldahir et al. (2015) who reported that after 12 weeks in 70% shade, Tifway had NDVI of 0.495 and TifGrand had NDVI of 0.621 during summer months. Our lower NDVI measurements were likely a result of the permanent nature of our shade structures during the study, which likely led to greater canopy density loss over time.

For zoysiagrasses, Zeon, Zorro, Palisades, JaMur and Geo had NDVI in 30% shade during summer and fall months ranging from 0.58 to 0.62. These results agree with those of Zhang et al. (2016), who reported NDVI of these same zoysiagrass cultivars ranging from 0.58 to 0.63 under 31% shade level.

Rough mowing heights exhibited greater NDVI than fairway mowing heights for both zoysiagrass and bermudagrass cultivars in 70%, 80% and 90% shade, emphasizing the benefit of increasing mowing heights on photosynthetic efficiency in heavy shade.

Finally, trinexapac-ethyl also improved NDVI of fairway height turf under 30, 50, and 70% shade in summer, and 30, 70, 80, and 90% shade in fall. Several previous studies also reported trinexapac-ethyl benefits on shaded turf health and performance, which include reduced leaf elongation, increased leaf rigidity, improved wear tolerance, and improved lateral growth (Stier and Rogers, 1999; Steinke and Stier, 2003a; Steinke and Stier, 2003b).

Root Mass

With regard to root mass, Celebration bermudagrass had significantly greater overall root mass in our study than JaMur and Geo. Additionally, Palisades also had significantly greater root mass than JaMur. These results differ from those of Zhang et al. (2016) who reported no difference among cultivars Zeon, Zorro, Palisades, JaMur and Geo on root mass. Full sun had root mass for 0.273g, which was significantly greater than root mass for our 50% shade level. This result is consistent with Zhang et al. (2016) who also reported that full sun plants had significantly greater root dry weights than those grown at 61% shade levels for zoysiagrass cultivars grown in the greenhouse.

Shear Strength

Shear strength can provide an indication of relative stability of turf when exposed to traffic, and can be influenced by both above and below ground biomass attributes such as stolon, rhizome, and root development. Because shaded turf is generally more vulnerable to wear and traffic injury (Jiang et al., 2003), shear strength can offer another means of evaluating and comparing cultivar performance in the shade environment. Zoysiagrass cultivars in our study generally had much higher shear strength than bermudagrass cultivars. When pooled across all shade levels, it was found that Zeon, Zorro, JaMur, and Geo all had exceptional shear strength, while TifGrand and Palisades had good shear strength, and Tifway, Celebration, Latitude 36 had fair shear strength. This may have been largely due to the fact that 5 of the 6 treatments in our study had some level of shade, and bermudagrass is generally intolerant of shaded conditions while zoyisiagrass possesses moderate shade tolerance. Furthermore, it may also relate to the relative wear tolerance of the two species. Youngner (1961) reported that the zoysiagrass cultivars expressed greater wear resistance characteristics compared to bermudagrass. Not surprisingly, shear strength also decreased as shade level increased. This is likely related to the shift from below to above ground allocation of plant biomass which occurs under shaded conditions (Dudeck and Peacock, 1992), which could have reduced the amount of laterally growing rhizomes and/or root biomass present to offer resistance to shearing.

Daily Light Integral (DLI)

Minimally acceptable turf quality in our study was achieved in the zoysiagrass cultivars with lower DLI levels than bermudagrass across all seasons. At fairway mowing heights without TE application, minimal DLI requirements across all cultivars ranged from 8.6 to 33.9 $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 19.8 to 25.7 $mol \cdot m^{-2} \cdot d^{-1}$ in summer, and 11.9 to 23.4 $mol \cdot m^{-2} \cdot d^{-1}$ in fall. Zoysiagrass cultivar minimal DLI requirements ranged from 8.6 (Zeon) to 20 (Geo) $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 19.8 (Zorro) to 21.7 (JaMur) $mol \cdot m^{-2} \cdot d^{-1}$ in summer, 11.9 (Geo) to 16.4 (Zorro) $mol \cdot m^{-2} \cdot d^{-1}$ in fall, in the absence of TE. In comparison, bermudagrass cultivar minimal DLI requirements ranged from 26.8 (TifGrand) to 33.9 (Tifway) $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 24.7 (Latitude 36) to 25.7 (Tifway) $mol \cdot m^{-2} \cdot d^{-1}$ in summer, and 16.5 (TifGrand) to 23.4 (Tifway) $mol \cdot m^{-2} \cdot d^{-1}$ in fall. Interestingly, DLI requirements differed by season, with most cultivars requiring the lowest DLI in spring and/or fall compared to summer. Achievement of high levels of turf quality with lower DLI in fall indicates that temperature may interact with light to influence quality differently between summer and fall/spring seasons, and also suggests the importance of photosynthesis/ respiratory balance. The findings are consistent with those of McBee and Holt (1966), who reported that Tifway, Meyer zoysia and common St. Augustinegrass all improved in density and ground cover in October and later in the season, despite lower levels of solar radiation. Furthermore, they agree with findings of Zhang et al., (2016) who reported that cultivar DLI requirements were lower during fall and spring months when compared to summer in short-term greenhouse experiments. It should also be noted that spring DLI requirements could be influenced by extent of winter dormancy and rate of spring green-up between cultivars. For example, *Zoysia matrella* cultivars (such as Zorro, Zeon, and Geo) have been observed to retain green color throughout the winter in the south-central U.S. at the same time that bermudagrass cultivars may experience shoot dormancy. Zoysiagrasses also have greater ability to withstand low temperature stress during winter compared with bermudagrasses (Beard, 1973; Rogers et al., 1977).

At the rough mowing height, minimal DLI requirements across all entries ranged from 2.1 to 29 $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 14.2 to 30.0 $mol \cdot m^{-2} \cdot d^{-1}$ in summer, and 9.2 to 17.3 $mol \cdot m^{-2} \cdot d^{-1}$ in fall. Zoysiagrass cultivar minimal DLI requirements ranged from 2.1 (Zeon) to 8.3 (Palisades) $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 14.2 (Zorro) to 18.8 (Palisades) $mol \cdot m^{-2} \cdot d^{-1}$ in summer, and 9.2 (Palisades) to 9.9 (Zeon) $mol \cdot m^{-2} \cdot d^{-1}$ in fall. Bermudagrass cultivar minimal DLI requirements were much higher, ranging from 5.7 (Celebration) to 28 (Tifway) $mol \cdot m^{-2} \cdot d^{-1}$ in spring, 23 (Celebration) to 30 (TifGrand) $mol \cdot m^{-2} \cdot d^{-1}$ in summer, and 13.8 (Celebration) to 17.3 (Tifway) mol·m^{-2}·d^{-1} in fall. The shade tolerant check Palmetto St. Augustinegrass required a minimal DLI of 8.8 mol·m^{-2}·d^{-1} in spring, 16.6 mol·m^{-2}·d^{-1} in summer, 11.3 mol·m^{-2}·d^{-1} in fall. When comparing rough to fairway mowing heights, increased mowing height led to reduce DLI requirements for most cultivars. This may partially explain the extremely high DLI requirements previously reported for ultradwarf bermudagrass putting green cultivars, which are commonly mowed at less than 0.5 cm. DLI requirements for Tifdwarf and Floradwarf have been reported to be nearly 39 mol·m^{-2}·d^{-1}, while TifEagle has been reported to require close to 32 mol·m^{-2}·d^{-1} to maintain acceptable quality (Bunnell et al., 2005b; Miller et al., 2005).

TE application on fairway height turf reduced DLI requirements across all entries from 25.3 to 15.8 mol·m^{-2}·d^{-1} in summer and from 19.8 to 8.7 mol·m^{-2}·d^{-1} in fall. Zoysiagrass cultivar minimal DLI requirements with TE applied ranged from 15.8 (Zorro) to 18.9 (Geo) mol·m^{-2}·d^{-1} in summer and from 8.7 (Geo) to 12.2 (Zeon) mol·m^{-2}·d^{-1} in fall. Bermudagrass cultivar minimal DLI requirements with TE applied ranged from 21.7 (TifGrand) to 25.3 (Tifway) mol·m^{-2}·d^{1} in summer and from 14 (TifGrand) to 19.8 (Tifway) mol·m^{-2}·d^{-1} in fall. Reduction in minimal daily light requirements due to TE application has been reported previously only for 'TifEagle' Bermudagrass, which required only 4 hours of direct sunlight per day to achieve acceptable quality compared to untreated plants, which required 8 hours per day.

Conclusions

This field study sought to examine comparative shade tolerance and DLI requirements of bermudagrass and zoysiagrass cultivars as influenced by mowing height and trinexapac-ethyl application. Furthermore, it aimed to determine whether DLI requirements change seasonally. Our results demonstrated that zoysiagrass cultivars achieved superior turf quality, maintained higher levels of green cover, had higher NDVI levels, higher shear strength measurements, and had overall lower DLI requirement than bermudagrass cultivars under moderate to heavily (50-90% shade) shaded conditions. Relative zoysiagrass performance varied between seasons. Most bermudagrass cultivars were able to maintain acceptable quality only within full sun or 30% shade conditions, and Tifway lacked shade tolerance relative to the other bermudagrass cultivars used. Monthly TE application (0.2 kg ai ha^{-1} per month) during summer months and increased mowing heights simulating golf course rough also improved turf quality and performance of all cultivars under low-light conditions. Seasonal differences in DLI were also noted across cultivars, with highest DLI requirements observed in summer and reduced DLI occurring in spring and fall seasons. There are some low cost DLI sensors available in the market now, combine with our DLI data, it will help to make better recommendations. Collectively, these data provide the useful information that can be used to guide more accurate, seasonally based recommendations on appropriate species and cultivar selection for shade environments, information that will also help to promote more sustainable turfgrass management.

CHAPTER III

NITROGEN FERTILITY AND GROWTH REGULATOR INTERACTIONS ON TIFWAY BERMUDAGRASS PERFORMANCE IN SHADE

Overview

Managing bermudagrass is a challenge in shaded environments. While considerable published research has focused on effects of nitrogen (N) management and/or use of growth regulators on quality and persistence of other warm-season turfgrasses in shade, there is little to no published data available regarding these combined factors on the shade tolerance of hybrid bermudagrass cultivars commonly used in golf or athletic turf situations. This greenhouse study was conducted in three light environments (Full Sun, 30% and 50% shade), evaluating the effects of N and Trinexapac-ethyl (TE) on 'Tifway' bermudagrass (*Cynodon dactylon* (L.) Pers. x *Cynodon transvaalensis* Burtt Davy) performance over a 12-week period. The objectives of this greenhouse study were to 1) determine the individual and combined effects of TE and high vs. low N rates on shaded Tifway bermudagrass, 2) determine whether potential detrimental effects of increased N on shaded Tifway bermudagrass can be offset by use of TE, and 3) determine effects of increasing shade levels on TE-induced growth suppression and metabolism. Our results demonstrated that TE (0.1 kg ai ha^{-1} per 14 days) application combined with low N rate (9.96 kg N ha^{-1} per 14 days) benefited shaded Tifway bermudagrass in terms of both turf quality and percent green cover. However, N rate alone failed to affect turf quality or percent green cover of Tifway bermudagrass under the shade environment. Also, high N rate (24.4 kg N ha-1 per 14 days) with TE

application contributed to better turf quality than high N rate without TE application. The high N rate (24.4 kg N ha^{-1} per 14 days) contributed to greater clipping yields in Tifway bermudagrass under both full sun and shade environments, while TE application alone failed to affect clipping yields. These data provide useful information to turf managers for maintaining Tifway bermudagrass in shaded environments.

Introduction

Maintaining high quality bermudagrass turf specially ‘Tifway’ bermudagrass (*Cynodon dactylon* (L.) Pers. x *Cynodon transvaalensis* Burtt Davy) in shaded environments can be challenging. Past research has demonstrated that proper nitrogen (N) management and/or use of growth regulators can improve quality and persistence of some species (Zoysia sp., Agrostis sp., Cynodon dactylon sp.) in shade. However, little to no research has examined the combined influence of N rate and growth regulator application on the shade tolerance of bermudagrass cultivars commonly used in golf or athletic turf situations.

Trinexapac-ethyl (TE) has become a routine component of management programs for turfgrass managers, particularly on golf course putting greens (McCullough et al., 2006). Adams (1992) showed that TE inhibits gibberellic acid (GA) production, so that vertical shoot growth is slowed. Gibberellin biosynthesis inhibitors such as paclobutrazol {(αR,βR)-rel-β-[(4- chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol}, flurprimidol {α-(1-methylethyl)-α-[4-(trifluoromethoxy)phenyl]-5-pyrimidine- methanol}, and TE, have also shown promise in improving quality and persistence of turfgrass in shade (Qian and Engelke, 1999; Stier et al., 1999; Stier and Rogers, 2001; Goss et al., 2002; Steinke and Stier, 2003a; Steinke and Stier, 2003b). Plant growth regulators of this type reduce cell elongation and therefore result in a more compact, dense stand of turfgrass with increased carbohydrate reserves (Qian and Engelke, 1999; Goss et al., 2002). TE applied at 96 g a.i. ha^{-1} resulted in 96 and 827% more tillers unit area for ‘Meyer’ zoysiagrass (Zoysia *japonica* Steud.) grown under 77 and 89% shade, respectively (Ervin et al, 2002). Plant growth regulators may also promote other characteristics of turfgrass quality that enhance tolerance to stress. For example, TE has been shown to indirectly improve turfgrass quality through increased leaf rigidity, resulting in improved wear tolerance and improved lateral growth (Stier and Rogers, 1999; Steinke and Stier, 2003a; Steinke and Stier, 2003b).

Nitrogen promotes plant growth, and is the most dynamic and important nutrient for turfgrasses considering its effects on color, density, recuperative ability, and plant health when applied at adequate rates (Carrow et al., 2001; Hull and Liu, 2005; Liu et al., 2008). Reducing turfgrass N inputs has proven beneficial for shaded environments. Burton et al. (1959) reported a high N rate (294 kg ha^{-1} Yr^{-1}) in 64% shade decreased 'Coastal' bermudagrass carbohydrates by 30% and also decreased plant density and leaf area compared to a low N rate (36 kg $ha^{-1}Yr^{-1}$). Similarly, Baldwin et al. (2009) reported significantly improved 'Champion' ultradwarf bermudagrass quality in shade when turf was supplied with 40% reduced N inputs (147 kg N ha^{-1} yr^{-1}) (McCarty and Miller, 2002). Similar benefits from reduced N in shade have also been reported for cool-season turf-grasses (Schmidt and Blaser, 1967; Bell and Danneberger, 1999; Goss et al., 2002). Bunnell (2005) reported that TE and mowing height significantly lowered the minimal DLI needed for acceptable quality of 'TifEagle' bermudagrass greens, but that N rate had no effect.

Baldwin (2009) conducted a two-year field study on Champion Bermudagrass evaluating the effects of Nitrogen and TE where he reported that Champion

Bermudagrass quality was improved with reduced N rate with routine TE application. Although reduced N rates and growth regulators have shown promise when used alone on shaded warm-season turf, the extent to which combinations of the two may be utilized is an area of research that has not been fully explored. Bermudagrass has a relatively high N requirement relative to other turf species (Cisar, Snyder, & Park, 2007), and as such, may not tolerate reduced N inputs in shade, especially in highly trafficked athletic turf situations. Therefore, it would be of interest to examine the extent to which both N and growth regulators could be used in combination to achieve optimal turf quality for turfgrass cultivars managed under shade.

The objectives of this greenhouse study were to 1) determine the individual and combined effects of TE and high vs. low N rates on shaded Tifway bermudagrass, 2) determine whether potential detrimental effects of increased N on shaded Tifway bermudagrass can be offset by use of TE, and 3) determine effects of increasing shade levels on TE-induced growth suppression and metabolism.

Materials and Methods

This study was conducted at the Texas A&M University Borlaug Center for Plant Research Greenhouses, College Station, Texas. The experiment was initiated on 19 August 2016 and was conducted through 18 November 2016. Greenhouse temperatures were set to 18 to 24°C with a 12-hr photoperiod (0600 to 1800 h), and 20 to 22°C from 1800 to 0600 h. The greenhouse caused a 22% reduction in photosynthetic photon flux relative to ambient solar radiation.

Three light environments (full sun=0%, 30%, and 50% shade) were used to evaluate the effects of N level and TE on turf performance over a 12-week period. Within each light environment, treatments were arranged in a completely randomized block design with 4 replicate pots per treatment. A factorial structure was used to test all combinations of N rate (low=9.76 kg N/ha/14 days vs. high=24.4 kg N/ha/14 days applied as ammonium sulfate) and TE application (0 or 0.1 kg ai/ha/14 days). Washed sod plugs (14 cm x 14cm square) were established into a USGA root zone sand in full sun conditions in 15 cm x 15 cm x 20 cm deep square pots for 4 weeks prior to initiating experiment. Soils were amended with macro- and micronutrients prior to sod establishment using Hi Mag Trace Element Package (Andersons, Inc., Maumee, OH) at a rate of 14 g m^{-2}, as well as 0-18-0 super phosphate (Bumper Crop Ag Services, Shulenberg, TX) at a rate of 9.8 g P m^{-2} at the initiation of the study. Pots were watered 3 times weekly to prevent wilt and clipped twice weekly at 1.9 cm clipping height using a ruler and scissors.

N and TE were applied to select treatments using a CO_2 powered backpack sprayer with XR Teejet 8002VS nozzles (Spraying System Co., Wheaton, IL) at 40 psi on weeks 0, 2, 4, 6, and 8. Root samples were taken after week 13 to determine root weights. After the roots samples were washed, the thatch layer was removed leaving only the root zone, which was immediately put into an oven and dried at 65 ^{o}C for 72 hours then weighted.

Turfgrasses were trimmed weekly and clippings were collected on weeks 1, 3, 5, 7, 9, 11, 12, and 13. After the clippings were collected, they were oven-dried at 65 ^{o}C for

72 hours before being weighed. Visual quality ratings and digital images of pots were also collected on weeks 0, 2, 4, 6, 8, and 10. Visual quality readings were taken immediately after the trimming, and rated on a scale from 1 to 9 where 1 = dead, 9 = ideal, and ≥6 minimally acceptable. Digital images were taken with a digital camera (Canon PowerShot SX-170 IS, Tokyo, Japan), which was mounted on a custom light box equipped with 2 LED flash light bulbs (NightStick, BAYCO Products inc., Wylie, TX) in order to quantify percent green cover using Sigma Scan Pro (Systat Software, Inc., San Jose, CA). We convert each time data to relative percent green cover in order to obtain more clearly percent green cover readings.

Data for each parameter were subjected to analysis of variance using the general linear model, univariate test procedure using SAS (SAS Institute Inc., Cary, NC) to determine statistical significance of the results. Where analysis of variance indicated a significant study effect, parameters were presented separately by study. Mean separation procedures were performed using Fisher's Least Significant Difference test at $P \leq 0.05$ level. Figures were created by SigmaPlot (Systat Software, Inc., San Jose, CA).

Results

Turf Quality

Week and primo treatments significantly affected turf quality for each shade treatment. For the full sun treatment, turf quality was significantly affected by N rate ($P<0.01$), TE ($P<0.05$) and N rate x TE interaction ($P<0.01$). Week x primo interaction was significant at 30% shade treatment. For 50% shade level, turf quality was significantly affected by TE ($P<0.001$), week x TE interaction ($P<0.001$), and N rate x

TE (P<0.05) (Table 29). No significant effects of shade or TE were detected for root dry weight data.

For full sun, high N rate with primo application always resulted in the highest turf quality reading (~8.5), and declined to only ~7 once N and TE application were ended after week eight. High N rate with no TE application also supported good turf quality (>8) until week eight (Figure 13).

Within the 30% shade level, all treatments experienced a decline in turf quality soon after shade was imposed (Figure 14). However, at these mild shade levels, low N combined with TE application resulted in the best performance, providing consistently good quality through week eight. High N with TE application also maintained good turf quality throughout most of the initial 8 weeks. Although they maintained acceptable turf quality (>6), there were no significant differences between the high N/ - TE and the low N/ - TE treatments, as both experienced gradually decreasing turf quality over the study period. Following termination of N and TE applications at week 8, all treatments receiving TE showed significantly improved turf quality relative to non-TE treatments through the end of the study (Figure 14).

Within the 50% shade level, similar treatment responses were observed relative to the 30% shade level (Figure 15). However, there were greater differences detected between the TE vs. non-TE treatments, and up until week eight, addition of TE resulted in turf quality at or above 7, while no TE application resulted in turf quality only around 6, regardless of N rate (Figure 15).

Table 29. Analysis of Turf Quality (TQ), Relative Percent Green Cover (RpctGn) and Clippings for the effects of Week, Nitrogen (N) Rate and Trinexapac-ethyl (TE) application on Tifway Bermudagrass under Full Sun, 30% and 50% shade level at Borlaug Center for Southern Crop Improvement, College Station, TX.

	P values								
	Full Sun			30% Shade			50% Shade		
Source	TQ	RpctGn	Clippings	TQ	RpctGn	Clippings	TQ	RpctGn	Clippings
Rep	NS	NS	**	***	**	NS	***	*	NS
Week	***	***	***	***	***	***	***	***	***
Nrate	**	*	***	NS	NS	***	NS	**	**
TE	*	NS	***	***	***	NS	***	***	NS
Week*Nrate	NS	**	NS	NS	NS	NS	NS	NS	NS
Week*TE	NS	***	**	**	***	NS	***	***	NS
Nrate*TE	**	***	NS	NS	NS	NS	*	*	NS

* Significant at 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
NS, not significant at $P \leq 0.05$.

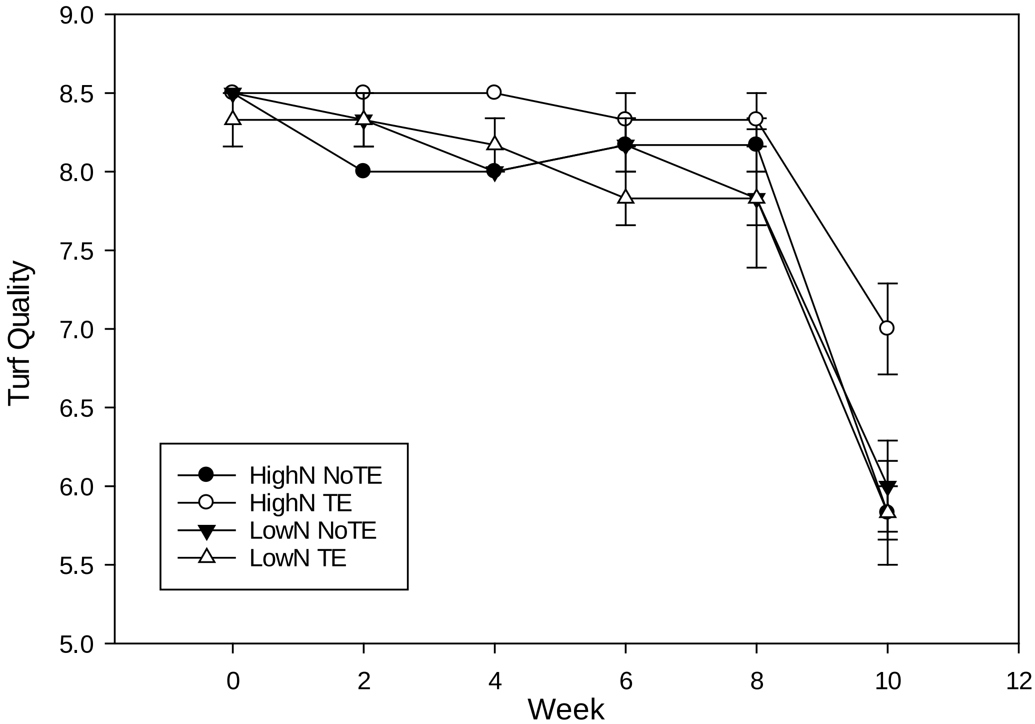

Figure 13. Turfgrass quality of Tifway Bermudagrass when grown under Full Sun at the Borlaug Center for Southern Crop Improvement, College Station, TX. Visual turfgrass quality (1 to 9 rating scale; 6 = minimally acceptable) was rated every two weeks for 10 weeks. TE and N applications were ended at week eight. Bars represent standard error.

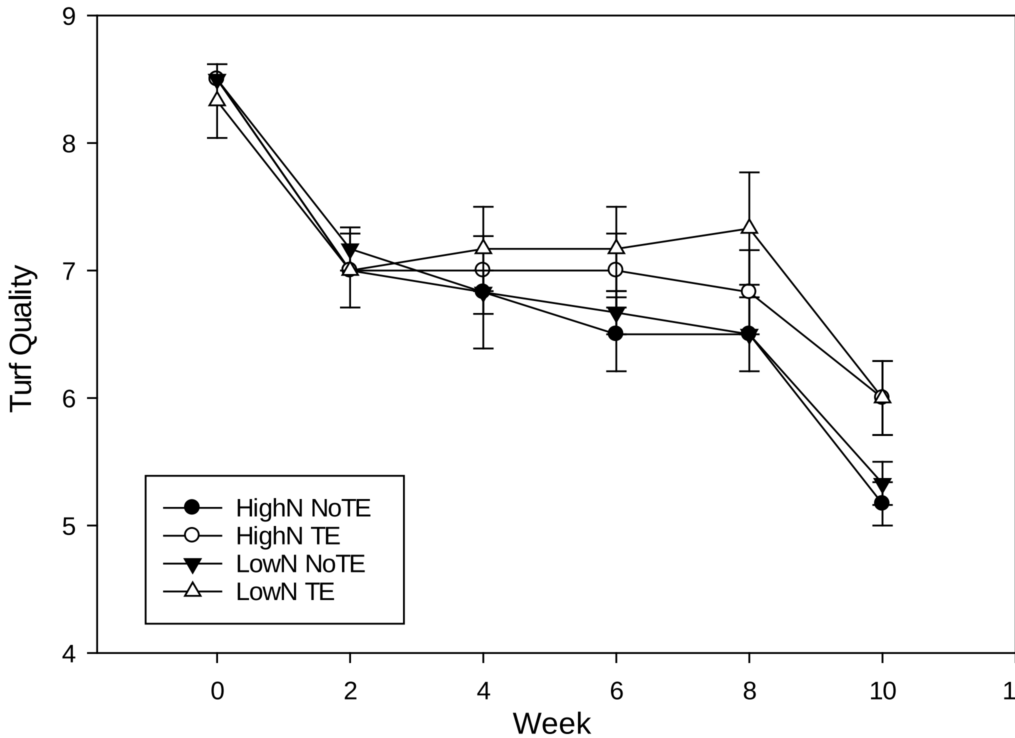

Figure 14. Turfgrass quality of Tifway Bermudagrass when grown under 30% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Visual turfgrass quality (1 to 9 rating scale; 6 = minimally acceptable) was rated every two weeks for 10 weeks. TE and N applications were ended at week eight. Bars represent standard error.

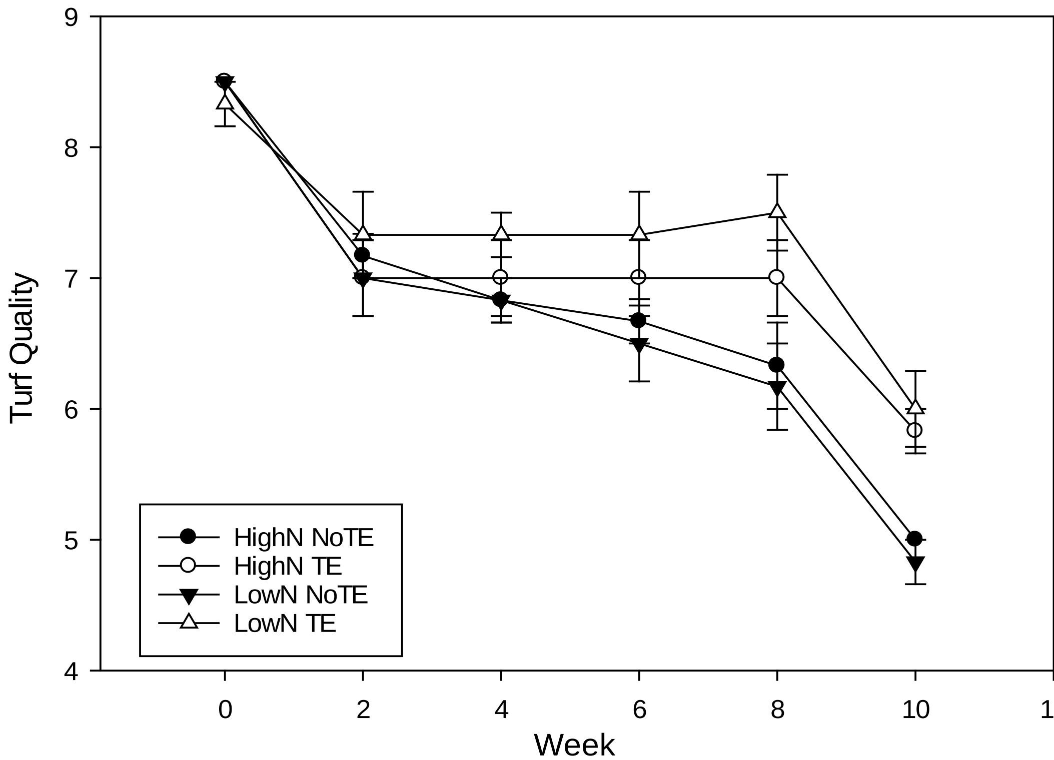

Figure 15. Turfgrass quality of Tifway Bermudagrass when grown under 50% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Visual turfgrass quality (1 to 9 rating scale; 6 = minimally acceptable) was rated every two weeks for 10 weeks. TE and N applications were ended at week eight. Bars represent standard error.

Relative Percent Green Cover

Week and week x TE interaction significantly affected relative percent green cover for all shade treatments. There were significant impacts from N rate ($P<0.05$), week x N rate interaction ($P<0.01$), week x TE interaction ($P<0.001$) and N rate x TE ($P<0.001$) interaction on relative percent green cover at full sun. For 30% shade level, relative percent green cover was significantly affected by TE ($P<0.001$) and week x TE interaction ($P<0.001$). N rate ($P<0.01$), TE ($P<0.001$), week x TE interaction ($P<0.001$) and N rate x TE ($P<0.05$) interaction were significant at 50% shade level (Table 29).

Within 30% shade, there was a percent green cover reduction in each treatment on week four (Figure 16). High N/ + TE treatments consistently maintained relative percent green cover above 80%, but low N/ + TE treatments consistently maintained the highest green coverage through week 8, and even to week ten. Both of the aforementioned treatments exhibited significantly greater green cover than - TE treatments after week six (Figure 16).

In 50% shade, there was a relative percent green cover reduction on week four, similar to that observed in the 30% shade level. However, in 50% shade, there were not significant differences detected between high N/ + TE treatments and low N/ + TE treatments, asboth maintained around 80% percent green cover through the duration of the study period. These treatments also provided greater green cover compared with - TE treatments at both weeks eight and ten. Low N/ - TE treatments showed the lowest green coverage thoughout the entire study at 50% shade levels (Figure 17).

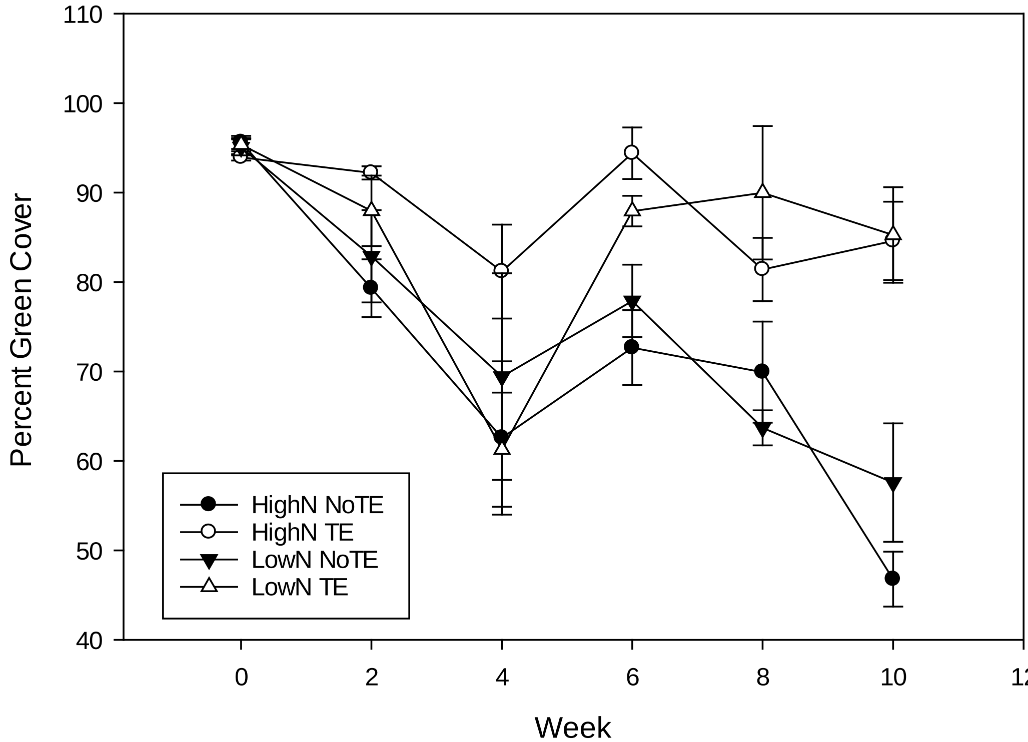

Figure 16. Turfgrass Relative Percent Green Cover of Tifway Bermudagrass when grown under 30% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Digital Images were taken every two weeks for 10 weeks. TE and N application were ended at week eight. Bars represent standard error.

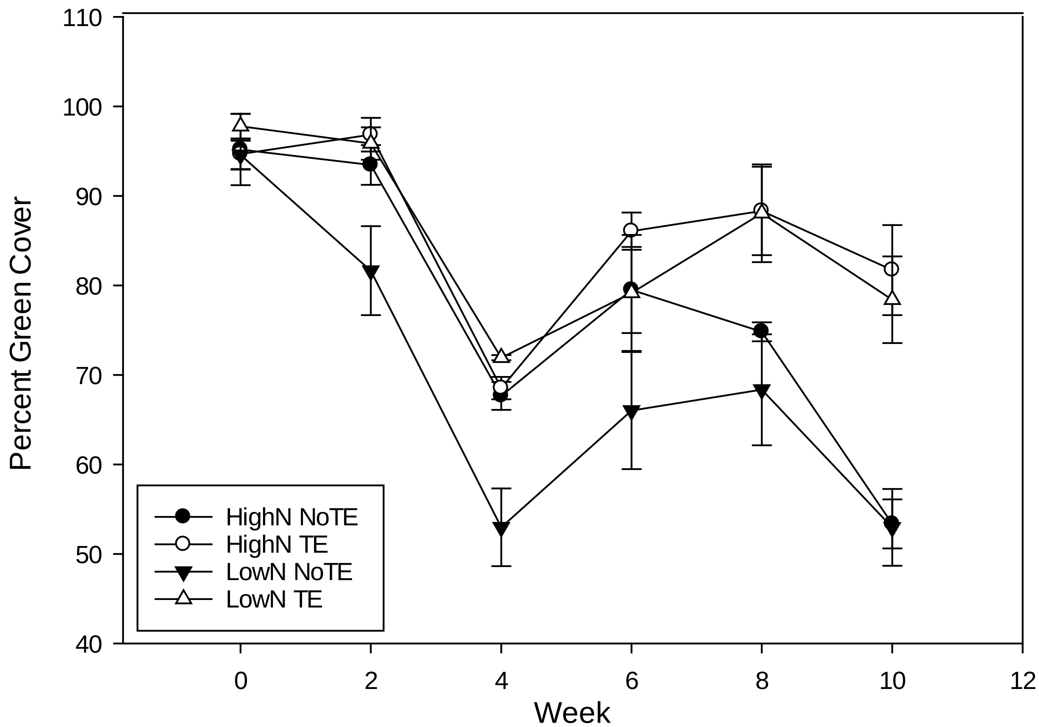

Figure 17. Turfgrass Relative Percent Green Cover of Tifway Bermudagrass when grown under 50% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Digital Images were taken every two weeks for 10 weeks. TE and N applications were ended at week eight. Bars represent standard error.

Clipping Dry Mass

Week and N rate significantly affected clippings for all shade treatments. There were also significant TE ($P<0.001$) and week x TE interactions ($P<0.01$) for clipping dry mass under full sun (Table 29).

In full sun, all treatments exhibited decline in clipping yield from beginning to end of the study period week (Figure 18). The pot edge was also trimmed for collecting the clippings, which may explained the higher amount of clippings collected from the high N/ + TE treatments had from week one to week nine. The low N/ - TE treatment had a significantly greater amount of clippings than high N/ - TE treatment on week one, but this trend reversed, and there wasn't a significant difference between these two treatments after week 5 Low N/ + TE treatments had the least amount of clippings throughout the entire study (Figure 18).

In 30% shade, data were pooled across TE levels. High N treatments always maintained clipping dry mass yields above 0.7 grams from weeks one to nine, which were significantly greater than low N treatments (Figure 19). Clipping dry mass yield within both N rates were reduced after week nine, although the high N treatments still produced greater clipping yields.

For 50% shade, data were also pooled across TE levels. Clippings decreased as week increased, but high N generally resulted in higher clipping yields relative to low N, especially on weeks 10 and 12 (Figure 20).

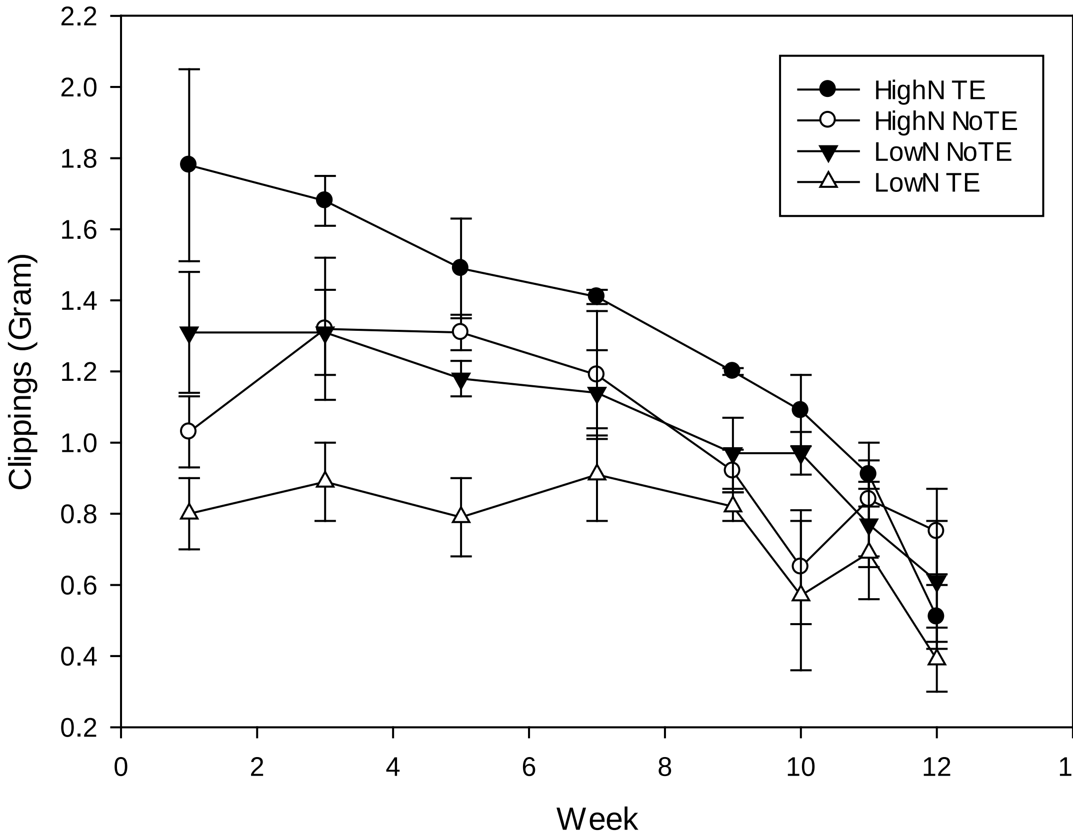

Figure 18. Clipping dry mass of Tifway bermudagrass when grown under full sun at the Borlaug Center for Southern Crop Improvement, College Station, TX. Data are pooled across Primo levels. Pots were trimmed weekly but clippings were collected every two weeks for eight weeks, and then weekly for the weeks nine through 12. TE and N applications were ended at week eight. Bars represent standard error.

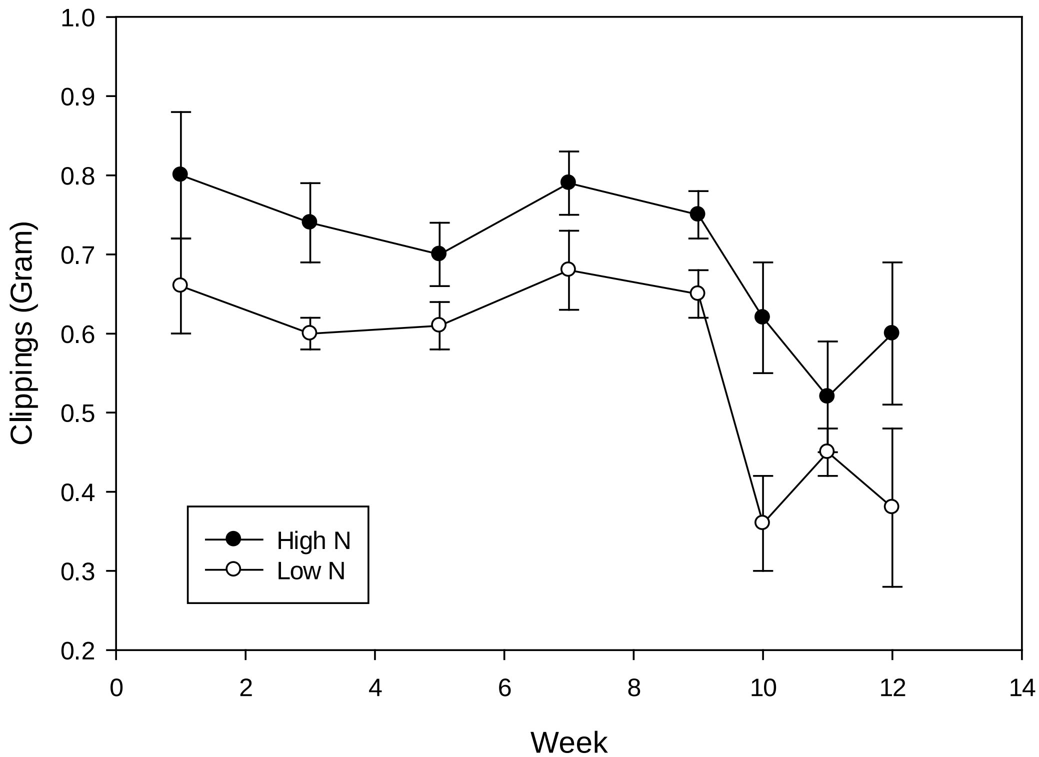

Figure 19. Clippings of Tifway Bermudagrass when grown under 30% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Data are pooled across Primo levels. Pots were trimmed weekly but clippings were collected every two weeks for eight weeks, and then weekly for weeks nine through 12. TE and N applications were ended at week eight. Bars represent standard error.

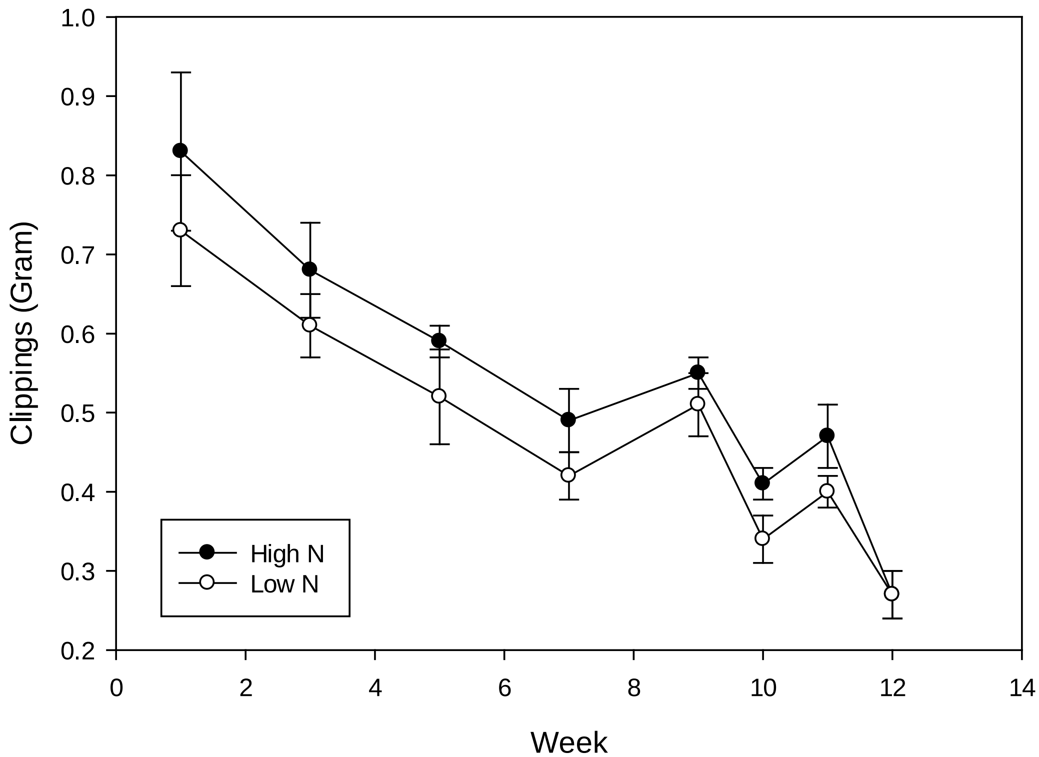

Figure 20. Clippings of Tifway Bermudagrass as affected by N rate when grown under 50% shade level at the Borlaug Center for Southern Crop Improvement, College Station, TX. Data are pooled across Primo levels. Pots were trimmed weekly but clippings were collected every two weeks for eight weeks, and then weekly from weeks nine through 12. TE and N applications were ended at week eight. Bars represent standard error.

Discussion

Turf Quality and Percent Green Cover

High N rate with primo application provided the best turf quality among all treatments in full sun (Figure 13). These results agree with Trenholm et al. (1998) who reported that N fertilization increased hybrid bermudagrass shoot growth. Qian and Engelka (1999) reported that TE reduced cell elongation and increased carbohydrate reserves, thereby resulting in a more compact and dense turf.

Under 30 and 50% shade levels, TE applications provided improved turf quality compared to - TE treatments (Figure 14, Figure 15). These results agree with those of Baldwin et al. (2009) who reported that TE application improved Champion bermudagrass turf quality under shaded environments. Within the TE applications, low N/ + TE treatments led to superior turf quality compared to high N/+ TE treatments (Figure 14, Figure 15). These results are consistent with findings of Baldwin et al. (2009), who found that reduced N rates provided improved turf quality compared to higher N rates under shade treatments.

Under the shaded environments, percent green cover data were consistent with turf quality data. As such, Primo applications provided the greatest green coverage but there was no detectable difference between high N/ + TE and low N/ + TE. Furthermore, low N/ + TE provided the lowest relative percent green coverage (Figure 16, Figure 17).

Clippings

In this study, the edge of the pots were trimmed for collecting overhanging stolons, and these were combined with clippings. This likely explains the elevated clipping dry weights observed for high N/ +TE plants. TE reduces vertical growth, but has also shown the potential to enhance lateral growth (Fagerness et al., 2000; Murphy et al., 2005). Low N/ + TE also resulted in the lowest clippings yields (Figure 18). These results agree with those from Baldwin et al. (2009) who reported that Champion bermudagrass had less clipping yield under full sun with TE application.

Under the shade treatments, only the N rate main effect was observed. As such, high N rate provided more clipping yield than low N rate (Figure 19, Figure 20). This result also agrees to Baldwin et al. (2009) who report that Champion bermudagrass under 55% shade environment, high nitrogen rate had greater clipping yields than under low N rate. At the 30% shade level, clipping yield was stable until week nine, but declined two weeks after the N and TE applications were ended (Figure 19). In 50% shade, clipping yields declined from the second clipping collection through the end of study (Figure 20). However, a rebound in clippings occurred one week after the N and TE applications were ended. In this way, it appears that high N in combination with the heavier shade level may have promoted more rapid metabolism of TE, resulting in a faster rebound effect. Gardner and Wherley (2005) have suggested that metabolism of TE by shaded turfgrass may occur at a different rate than in full sun, which could influence recommended rates and timings, depending on shade intensity. Limited to no research has investigated the metabolism of TE on warm-season turfgrass in the shaded environment.

Conclusions

In this study, TE (0.1 kg ai ha^{-1} per14 days) application combined with low N rate (9.96 kg N ha^{-1} per 14 days) benefited shaded Tifway bermudagrass in terms of both turf quality and percent green cover. However, N rate alone did not have a significant effect on turf quality or percent green cover of Tifway bermudagrass under the shade environment. Also, high N rate (24.4 kg N ha^{-1} per 14 days) with TE application contributed to improved turf quality compared to high N rate without TE application. The high N rate (24.4 kg N ha^{-1} per14 days) contributed to greater clipping yields in Tifway bermudagrass, under both full sun and shade environments. TE application failed to affect clipping yields in Tifway bermudagrass under shade environment. Collectively, these data offer insights on proper N and TE management for turf managers maintaining Tifway bermudagrass in low light situations.

CHAPTER IV

CONCLUSION

Managing high quality turf in shade can be a significant challenge for many turfgrass managers. Research is needed which utilizes the concept of minimal DLI to guide more accurate cultivar selection and more efficient turf management methods for shade environments. This field and greenhouse study were conducted to determine minimal daily light integral (DLI) requirements for zoysiagrass and bermudagrass cultivars with special emphasis on the interactions of fertility, mowing height, and growth regulators.

In the field study, we examined the comparative shade tolerance and DLI requirements of bermudagrass and zoysiagrass cultivars as influenced by mowing height and trinexapac-ethyl (TE) application. Furthermore, we sought to determine whether DLI requirements differed seasonally. Our findings demonstrated that zoysiagrass cultivars achieved superior turf quality, maintained higher levels of green cover, had higher NDVI levels, higher shear strength measurements, and had overall lower DLI requirement than bermudagrass cultivars under moderate to heavily (50-90% shade) shaded conditions. Relative zoysiagrass performance varied between seasons. Most bermudagrass cultivars were able to maintain acceptable quality only within full sun or 30% shade conditions, and Tifway noticeably lacked shade tolerance relative to the other bermudagrass cultivars used. Monthly TE application (0.2 kg ai ha^{-1} month) during summer months and increased mowing heights simulating golf course rough also improved turf quality and performance of all cultivars under low-light conditions. Seasonal differences in DLI were also noted across cultivars, with highest DLI requirements observed in summer and reduced DLI occurring in spring and fall seasons.

The greenhouse study was conducted in three light environments (full sun, 30% and 50% shade) to test the effects of nitrogen (N) and trinexapac-ethyl (TE) on ‘Tifway’ bermudagrass (*Cynodon dactylon* (L.) Pers. x *Cynodon transvaalensis* Burtt Davy) performance over a 12-week period. Our findings showed that TE (0.1 kg ai ha^{-1} per 14 days) application combined with low N rate (9.96 kg N ha^{-1} per 14 days) benefited shaded Tifway bermudagrass in terms of both turf quality and percent green cover. However, N rate alone failed to significantly affect turf quality or percent green cover of Tifway bermudagrass under the shade environment. Also, high N rate (24.4 kg N ha^{-1} per 14 days) with TE application contributed to a better turf quality than high N rate without TE application. The high N rate (24.4 kg N ha^{-1} per 14 days) contributed to greater clipping yields in Tifway bermudagrass under both full sun and shade environments. TE application also failed to affect clipping yields for Tifway bermudagrass.

Data will continue to be collected for another season in order to develop a longer-term, more comprehensive data set. However, the data presented herein provides useful information that can be used to guide more accurate, seasonally based recommendations on appropriate cultivars selection and turf management methods selection for shade environments. The data will also help contributed to more sustainable turfgrass management systems. In light of our findings, future research might address the influence of foot or cart trafficking on DLI requirements of these cultivars. It would also be of interest to determine how irrigation inputs, field N rates, or winter overseeding practices influence the DLI requirements that were identified through this project.

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APPENDIX A

TABLES

2015 September Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	40.9	29.6	27.2	19.6	20	12.5
TifGrand	34.5	32.1	40.0	37.9	33.8	27.4
Celebration	48.6	53.0	56.4	47.0	50.4	41.5
Latitude 36	76.3	83.1	76.5	77.8	57.1	65.7
Zeon	31.9	23.2	22.6	22.2	26.6	12.6
Zorro	32.3	25.3	26.2	36.4	36.4	20.8
Palisades	48.7	57.1	40.9	47.1	42.9	49.6
JaMur	28.8	37.5	39.1	32.8	39.3	25.8
Geo	31.2	57.5	63.3	47.0	64.9	31.8
LSD	21.9	31.21	28.8	38.6	26.2	29.9
Cutivar	***	***	***	**	***	***
			Rough			
Tifway	80.7	71.4	61.3	57.8	54.6	50.5
TifGrand	77.0	69.1	70.3	78.9	68.8	73.2
Celebration	83.1	82.8	78.7	76.0	75.8	75.2
Latitude 36	93.1	95.0	93.7	88.4	94.1	92.3
Zeon	93.2	81.8	69.8	75.9	76.2	75.1
Zorro	87.1	87.2	73.2	60.2	80.8	75.8
Palisades	89.4	82.6	73.2	69.6	82.9	78.7
JaMur	85.5	85.7	79.7	75.3	84.4	72.7
Geo	94.2	93.3	89.0	88.5	88.3	86.6
LSD	24.4	25.6	27.0	38.0	23.8	24.6
Cutivar	NS	NS	*	NS	**	**

2015 October Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	32.5	31.8	23.5	14.2	8.8	6.5
TifGrand	44.7	56.6	52.9	22.8	26.3	15.0
Celebration	52.3	35.9	40.0	16.8	22.8	11.9
Latitude 36	53.1	37.4	19.3	11.9	14.8	9.8
Zeon	60.7	61.8	53.1	43.0	42.3	30.0
Zorro	66.7	53.4	56.2	44.9	39.8	28.1
Palisades	83.0	73.3	63.6	40.8	39.1	30.7
JaMur	59.4	57.0	61.8	44.3	41.6	24.8
Geo	75.9	75.6	83.4	44.9	38.2	23.2
LSD	21.4	30.6	27.7	26.5	25.7	19.7
Cutivar	***	***	***	***	**	**
			Rough			
Tifway	44.3	37.8	38.5	21.4	17.7	12.1
TifGrand	60.9	53.2	55.5	29.8	38.1	17.3
Celebration	58.5	60.5	62.8	34.8	48.3	22.1
Latitude 36	48.7	34.0	30.8	16.0	21.7	14.8
Zeon	85.0	73.5	72.6	70.1	59.7	62.9
Zorro	63.7	75.9	74.0	51.6	65.6	51.1
Palisades	72.7	58.6	63.1	51.7	61.9	43.0
JaMur	72.0	68.9	67.5	56.8	60.0	62.2
Geo	86.0	84.4	87.7	70.6	70.8	50.7
LSD	26.6	25.5	26.5	27.3	35.8	22.8
Cutivar	***	***	***	***	***	***

2015 December Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	29.3	39.6	24.2	15.2	8.0	7.7
TifGrand	50.4	74.8	67.3	31.9	28.3	14.9
Celebration	46.6	66.8	52.1	31.8	32.6	30.0
Latitude 36	34.1	57.4	37.6	19.6	23.0	21.3
Zeon	47.9	62.4	49.7	42.6	35.2	31.0
Zorro	57.8	57.9	53.0	42.0	35.9	26.1
Palisades	73.1	85.5	74.0	60.7	37.7	28.8
JaMur	44.7	59.4	70.6	52.9	46.0	32.3
Geo	55.5	91.1	72.8	46.4	19.3	25.4
LSD	24.9	24.0	23.4	21.7	23.1	21.6
Cutivar	***	***	***	***	**	*
			Rough			
Tifway	20.5	48.7	42.5	23.8	18.5	12.8
TifGrand	25.2	55.9	72.9	48.2	39.8	28.7
Celebration	19.2	58.4	66.1	67.9	61.5	41.1
Latitude 36	12.4	42.3	41.6	46.9	37.7	31.1
Zeon	32.4	65.4	63.9	68.3	52.7	59.4
Zorro	35.6	62.3	69.5	45.8	54.9	33.8
Palisades	39.3	80.5	72.1	59.5	60.6	42.6
JaMur	38.0	70.7	72.5	64.5	68.3	66.8
Geo	64.6	78.7	86.0	62.9	59.7	31.7
LSD	13.4	24.4	21.7	24.6	27.5	21.3
Cutivar	***	***	***	***	***	***

2016 February Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	2.3	20.0	18.2	9.5	6.8	2.1
TifGrand	3.9	53.9	65.4	28.9	28.3	10.3
Celebration	2.3	45.9	61.4	50.5	57.4	47.5
Latitude 36	2.6	32.1	32.9	23.5	43.4	22.3
Zeon	8.6	36.2	29.1	34.0	26.0	24.8
Zorro	8.8	29.3	32.5	30.5	24.8	21.0
Palisades	16.0	53.4	71.2	62.2	44.1	34.4
JaMur	9.5	30.7	43.6	39.7	47.2	33.2
Geo	2.7	67.6	88.5	64.8	18.6	26.0
LSD	6.3	23.7	21.1	31.0	27.5	28.0
Cutivar	***	***	***	***	***	**
			Rough			
Tifway	0.7	11.8	18.5	11.5	6.7	4.2
TifGrand	1.2	27.9	39.6	35.6	27.3	17.8
Celebration	1.5	21.8	45.6	53.6	55.5	39.8
Latitude 36	0.8	12.4	28.0	40.0	35.8	36.8
Zeon	3.8	34.4	42.3	49.3	37.3	44.2
Zorro	3.5	32.1	43.8	35.9	42.5	31.4
Palisades	6.7	43.1	50.9	61.4	53.3	26.1
JaMur	6.9	31.5	46.0	50.0	62.1	58.0
Geo	23.4	64.0	83.0	74.6	72.8	41.1
LSD	4.2	14.5	18.7	20.2	30.1	28.1
Cutivar	***	***	***	***	***	***

2016 March Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	49.3	30.9	10.0	5.4	2.2	1.8
TifGrand	71.4	78.7	45.9	31.3	14.9	11.0
Celebration	75.7	68.8	41.5	12.3	13.1	5.8
Latitude 36	72.4	45.4	31.4	10.1	6.0	3.2
Zeon	60.2	92.2	81.0	65.2	47.8	23.4
Zorro	35.3	85.6	91.3	67.8	54.9	28.5
Palisades	70.7	80.4	68.2	38.1	22.5	9.9
JaMur	46.3	69.8	72.6	44.4	35.5	17.4
Geo	29.8	90.8	62.4	25.5	3.0	1.0
LSD	35.6	24.7	34.4	21.0	26.2	19.7
Cutivar	*	***	***	***	***	**
			Rough			
Tifway	34.4	58.6	44.9	33.4	27.8	15.1
TifGrand	32.2	89.1	75.3	60.9	57.9	40.1
Celebration	45.6	85.2	83.5	61.6	66.0	46.6
Latitude 36	56.3	93.7	75.5	71.9	62.3	51.9
Zeon	54.6	89.3	92.7	84.7	66.9	65.7
Zorro	85.2	97.1	95.2	80.9	86.0	41.3
Palisades	59.2	91.5	80.0	52.8	40.1	28.9
JaMur	55.8	80.2	91.8	80.9	66.6	57.8
Geo	72.4	87.3	81.1	58.4	57.0	27.5
LSD	22.6	16.9	22.9	27.3	36.3	25.6
Cutivar	***	***	***	***	**	***

2016 May Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	68.6	16.1	17.2	3.9	4.7	4.4
TifGrand	86.0	20.1	18.8	21.8	9.2	6.0
Celebration	67.3	10.5	12.9	7.2	5.0	5.8
Latitude 36	30.1	7.8	3.8	2.7	19.2	3.3
Zeon	95.7	70.6	61.5	25.6	17.8	7.9
Zorro	97.0	88.6	75.3	27.5	26.3	12.8
Palisades	87.9	41.0	32.9	14.7	18.4	12.1
JaMur	74.5	55.6	53.9	26.8	10.3	13.5
Geo	64.5	15.3	13.6	8.1	5.3	2.6
LSD	27.5	30.3	35.7	24.9	23.2	12.1
Cutivar	***	***	***	*	NS	NS
			Rough			
Tifway	68.6	20.3	13.7	15.3	14.5	6.8
TifGrand	73.6	67.3	50.4	42.0	26.2	17.2
Celebration	75.9	41.4	40.3	27.7	31.8	24.4
Latitude 36	88.1	39.8	30.3	16.7	12.0	11.5
Zeon	92.0	88.3	87.1	81.1	47.9	53.3
Zorro	94.6	93.5	87.5	72.9	71.6	45.2
Palisades	82.4	71.8	61.0	44.2	31.9	27.5
JaMur	84.2	88.7	80.4	66.9	54.6	48.1
Geo	93.2	88.3	74.8	58.5	46.9	25.3
LSD	25.7	21.4	16.4	13.1	24.4	22.0
Cutivar	*	***	***	***	***	***

2016 June Percent Green Cover

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	82.8	26.3	25.7	21.7	10.1	1.5
	+TE	87.9	33.1	26.4	35.7	21.3	6.3
TifGrand	-TE	93.8	72.3	44.4	33.6	16.7	5.8
	+TE	74.5	51.7	39.6	19.7	17.1	17.1
Celebration	-TE	71.9	40.5	25.5	25.3	17.4	2.1
	+TE	83.7	32.4	36.8	25.9	17.3	4.2
Latitude 36	-TE	66.1	35.8	23.2	28.0	11.1	5.3
	+TE	95.8	54.0	53.8	46.7	18.2	8.1
Zeon	-TE	97.5	73.8	56.2	27.2	13.3	4.5
	+TE	79.6	63.5	30.9	16.6	7.1	11.6
Zorro	-TE	97.9	64.6	67.5	23.8	27.6	7.8
	+TE	95.1	73.0	60.1	33.3	29.6	5.6
Palisades	-TE	87.5	75.9	62.6	32.6	25.0	8.2
	+TE	81.2	47.1	51.8	21.4	10.3	3.6
JaMur	-TE	92.2	84.5	76.0	41.7	12.3	13.2
	+TE	92.3	70.7	61.9	49.1	13.0	20.0
Geo	-TE	90.6	35.1	19.6	18.3	8.5	2.2
	+TE	56.8	84.4	58.9	32.3	31.1	3.4
LSD		35.2	59.7	41.6	31.3	35.2	23.9
Cutivar		NS	*	***	NS	NS	NS
Primo		NS	NS	NS	NS	NS	NS
Cutivar*Primo		*	NS	*	NS	NS	NS
				Rough			
Tifway		59.9	28.4	17.5	11.9	20.3	51.1
TifGrand		86.6	55.9	45.2	15.0	21.1	65.9
Celebration		70.0	38.9	45.0	19.7	23.1	59.4
Latitude 36		83.5	26.4	21.4	8.7	24.6	54.5
Zeon		94.3	84.3	71.2	32.8	21.5	53.0
Zorro		95.7	69.3	74.6	30.0	33.9	45.5
Palisades		89.4	61.2	57.8	25.9	32.0	57.3
JaMur		86.1	76.9	64.5	42.8	45.4	65.1
Geo		93.2	85.3	73.7	45.5	30.1	83.2
LSD		21.1	25.8	30.5	11.6	35.7	42.9
Cutivar		***	***	***	***	NS	NS

2016 July Percent Green Cover

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	33.3	27.3	27.6	26.9	18.5	3.8
	+TE	75.5	72.1	66.2	53.4	40.6	5.8
TifGrand	-TE	66.8	49.9	39.8	29.1	30.5	13.4
	+TE	77.1	74.0	69.8	62.8	42.7	22.5
Celebration	-TE	42.5	23.8	23.8	22.5	21.7	1.7
	+TE	73.3	76.2	72.9	54.6	42.5	6.7
Latitude 36	-TE	35.8	24.6	27.6	11.1	21.1	6.5
	+TE	74.7	76.1	71.4	45.3	46.3	10.4
Zeon	-TE	47.6	26.9	24.6	40.0	31.3	8.7
	+TE	93.4	93.6	91.2	65.0	37.8	9.0
Zorro	-TE	42.7	43.1	28.8	31.8	39.9	17.7
	+TE	78.9	83.8	87.5	71.4	50.6	24.0
Palisades	-TE	43.7	35.7	43.3	43.3	26.3	15.2
	+TE	79.0	81.1	83.3	69.6	37.5	11.8
JaMur	-TE	57.3	46.9	44.2	47.8	28.7	17.3
	+TE	85.0	82.1	79.5	69.8	42.3	21.5
Geo	-TE	57.7	31.1	42.4	28.6	19.6	4.4
	+TE	89.7	70.8	84.5	60.2	29.1	5.0
LSD		29.2	23.2	23.9	29.8	25.3	23.1
Cutivar		*	*	*	**	NS	**
Primo		***	***	***	***	***	NS
Cutivar*Primo		NS	*	NS	NS	NS	NS
				Rough			
Tifway		51.1	29.8	18.7	16.1	26.6	7.5
TifGrand		65.9	50.9	49.3	27.6	18.4	10.5
Celebration		59.4	30.9	46.3	25.7	18.2	2.3
Latitude 36		54.5	21.7	32.7	13.2	18.7	5.5
Zeon		53.0	46.9	44.2	32.2	36.4	7.3
Zorro		45.5	55.4	54.5	29.8	45.0	20.4
Palisades		57.3	66.0	64.5	48.6	42.5	25.3
JaMur		65.1	66.2	61.0	41.6	47.9	34.5
Geo		83.2	70.3	64.8	49.6	39.5	20.1
LSD		42.9	18.7	31.3	19.3	34.8	15.5
Cutivar		NS	***	**	***	NS	***

2016 August Percent Green Cover

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	30.7	36.5	25.3	24.2	21.5	8.2
	+TE	32.6	10.6	24.8	16.0	9.6	2.8
TifGrand	-TE	39.7	54.2	33.9	30.3	20.8	7.5
	+TE	47.2	38.6	27.8	16.5	21.1	4.4
Celebration	-TE	39.3	37.6	30.8	19.8	20.0	4.6
	+TE	43.3	21.2	25.7	14.9	18.1	1.7
Latitude 36	-TE	24.0	44.0	32.5	22.5	27.8	4.2
	+TE	33.2	25.9	29.4	22.0	29.4	3.7
Zeon	-TE	49.3	63.2	47.9	44.5	36.7	7.5
	+TE	51.3	31.0	49.3	24.1	29.0	18.8
Zorro	-TE	41.2	59.7	44.6	46.7	52.3	30.9
	+TE	41.7	36.9	54.0	41.9	41.9	19.1
Palisades	-TE	30.0	74.0	59.6	49.9	31.6	4.4
	+TE	55.0	42.3	66.6	60.5	47.1	10.9
JaMur	-TE	51.0	65.6	49.3	46.8	34.1	25.9
	+TE	70.3	65.7	68.3	56.5	57.7	19.3
Geo	-TE	45.9	80.5	55.1	45.6	21.6	15.2
	+TE	48.3	47.1	75.2	44.0	40.6	15.3
LSD		44.7	35.5	25.6	36.1	33.7	17.1
Cutivar		NS	***	***	***	**	***
Primo		NS	***	NS	NS	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		34.6	39.7	27.1	25.9	28.7	9.7
TifGrand		44.0	50.1	30.6	37.2	26.3	10.0
Celebration		47.8	48.7	44.5	30.8	32.3	6.4
Latitude 36		32.3	42.6	38.6	25.4	35.5	13.2
Zeon		47.2	67.9	60.0	48.0	46.7	17.6
Zorro		40.0	72.3	64.4	46.2	66.0	33.8
Palisades		27.9	64.5	56.2	55.2	61.3	35.0
JaMur		52.2	65.6	60.7	51.6	63.0	52.8
Geo		63.5	76.7	71.1	71.6	68.8	38.8
LSD		43.7	34.6	24.1	33.5	41.5	29.9
Cutivar		NS	*	***	**	**	***

2016 September Percent Green Cover

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	28.9	22.0	15.4	12.4	6.1	2.2
	+TE	59.9	56.3	47.2	30.9	23.8	18.9
TifGrand	-TE	50.6	49.5	36.8	22.5	9.7	2.4
	+TE	76.5	74.9	66.4	51.0	29.4	26.1
Celebration	-TE	65.9	50.7	49.8	20.4	14.0	4.3
	+TE	81.0	70.1	72.0	49.2	36.1	20.6
Latitude 36	-TE	56.7	43.5	36.8	23.5	17.3	3.0
	+TE	77.2	67.9	65.5	47.8	35.4	18.9
Zeon	-TE	44.4	60.5	45.4	44.4	27.5	18.3
	+TE	77.8	79.2	78.6	65.0	49.5	41.2
Zorro	-TE	56.3	57.1	50.2	52.5	50.6	17.2
	+TE	82.5	84.4	88.3	80.9	67.2	50.1
Palisades	-TE	64.9	68.1	58.2	49.2	41.3	13.1
	+TE	80.5	82.0	78.9	81.1	57.9	35.8
JaMur	-TE	70.9	64.4	61.5	53.6	44.7	29.3
	+TE	84.5	87.7	83.6	76.0	56.4	44.4
Geo	-TE	61.4	59.2	62.6	47.9	24.8	18.2
	+TE	86.3	83.6	90.5	79.0	60.0	42.2
LSD		30.6	32.1	24.0	27.3	34.3	25.1
Cutivar		**	***	***	***	***	***
Primo		***	***	***	***	***	***
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		64.6	69.7	37.6	19.4	27.2	4.7
TifGrand		83	74.2	67.3	38.8	18.9	5.4
Celebration		82.5	78.7	81.3	58.7	34.1	4.2
Latitude 36		76.6	70.1	63.9	39.1	37.1	5.5
Zeon		76.8	70	63.9	64.4	52.9	21.4
Zorro		60.5	75.9	70.2	58	69.9	31.1
Palisades		77.5	89.1	83.7	76.5	65.8	42.3
JaMur		78.9	85	81.6	71.7	70.1	50.1
Geo		90.5	92.3	90	86.1	72.6	45.2
LSD		30.932	26.969	21.282	31.173	41.612	23.829
Cutivar		NS	NS	***	***	***	***

2016 October Percent Green Cover

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	63.8	42.9	37.7	16.8	11.0	13.8
	+TE	61.0	44.9	32.8	14.1	9.5	9.5
TifGrand	-TE	89.5	71.8	68.7	32.6	15.9	10.7
	+TE	88.3	74.5	67.1	34.3	17.7	7.7
Celebration	-TE	80.8	58.5	52.8	23.0	18.1	9.4
	+TE	80.0	55.7	49.9	28.9	23.7	7.7
Latitude 36	-TE	81.5	51.0	48.8	26.9	19.5	8.6
	+TE	79.3	46.4	47.1	27.9	18.6	5.7
Zeon	-TE	79.3	64.6	63.7	35.2	31.2	18.2
	+TE	79.3	62.8	65.5	50.9	41.7	28.8
Zorro	-TE	86.0	67.5	60.8	51.6	39.2	28.0
	+TE	83.2	69.0	71.9	65.7	49.2	31.8
Palisades	-TE	91.0	73.1	76.3	49.6	39.5	15.6
	+TE	89.0	70.8	75.3	56.9	45.7	19.6
JaMur	-TE	91.3	79.8	76.1	54.3	44.1	28.1
	+TE	89.5	82.4	73.9	61.3	55.9	35.6
Geo	-TE	96.2	65.3	78.6	49.7	31.9	22.6
	+TE	94.2	69.2	85.2	68.4	51.1	33.3
LSD		14.0	14.8	14.8	18.6	33.4	19.7
Cutivar		***	***	***	***	***	***
Primo		NS	NS	NS	***	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		76.5	59.2	49.7	26.0	24.8	10.1
TifGrand		85.4	75.2	69.1	47.1	25.6	10.7
Celebration		80.4	70.1	68.1	57.1	39.8	8.4
Latitude 36		86.8	72.4	70.4	46.9	35.9	10.5
Zeon		90.8	70.6	69.9	63.5	51.2	29.5
Zorro		87.7	76.7	69.8	59.8	62.7	36.2
Palisades		92.9	83.8	80.9	68.1	60.6	50.4
JaMur		92.8	81.7	85.2	71.6	66.4	50.6
Geo		83.8	64.8	70.1	69.1	72.4	40.3
LSD		12.8	18.3	19.5	16.2	32.5	24.2
Cutivar		**	**	***	***	***	***

2016 November Percent Green Cover

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	75.3	60.5	53.1	26.2	24.0	21.6
TifGrand	86.1	67.3	61.6	46.3	36.6	20.9
Celebration	69.7	65.8	62.9	41.3	37.7	21.0
Latitude 36	84.1	65.2	61.0	40.0	44.6	21.5
Zeon	87.8	81.5	81.8	66.3	49.5	39.2
Zorro	87.4	82.1	84.5	71.5	60.6	40.2
Palisades	93.4	86.1	89.1	78.8	69.4	34.2
JaMur	93.3	89.6	86.9	76.1	59.4	35.7
Geo	91.0	90.1	97.5	87.0	70.7	45.9
LSD	12.3	10.6	10.0	23.1	31.5	18.9
Cutivar	***	***	***	***	**	***
			Rough			
Tifway	48.6	60.3	49.6	37.1	31.3	24.3
TifGrand	68.4	63.3	59.7	50.3	41.9	23.2
Celebration	52.8	64.7	62.1	55.7	50.1	22.8
Latitude 36	56.4	62.8	65.1	42.5	40.0	24.9
Zeon	84.8	77.1	78.9	73.2	49.6	42.9
Zorro	83.7	83.7	78.7	72.4	64.2	41.8
Palisades	87.5	81.9	82	76.6	67.3	53.0
JaMur	87.9	84.0	89.8	72.8	68.6	55.8
Geo	88.7	87.1	86.2	74.6	65.6	45.9
LSD	18.406	16.021	12.771	11.21	22.568	17.362
Cutivar	***	***	***	***	***	***

2015 September Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	6.1	5.5	5.8	5.1	5.3	5.6
TifGrand	6.1	6.0	5.9	5.8	5.9	6.0
Celebration	6.6	6.3	6.0	6.3	6.1	6.3
Latitude 36	6.9	6.8	6.8	6.8	6.6	6.5
Zeon	6.4	5.9	6.0	5.9	5.9	6.0
Zorro	6.1	5.6	5.9	5.8	5.8	5.6
Palisades	6.6	6.1	6.1	6.4	6.3	6.4
JaMur	5.9	5.6	5.9	5.6	6.0	5.4
Geo	5.9	6.0	6.1	5.6	6.1	5.5
LSD	0.9	1.4	1.0	0.9	0.8	1.0
Cutivar	*	NS	NS	***	**	*
			Rough			
Tifway	6.8	6.4	6.4	6.3	5.9	6.3
TifGrand	6.6	6.0	6.3	6.4	6.1	6.1
Celebration	6.9	6.3	6.6	6.5	6.1	6.5
Latitude 36	7.0	6.5	6.5	6.9	6.5	6.6
Zeon	6.8	6.4	6.4	6.4	6.3	6.6
Zorro	7.1	6.6	6.8	7.1	6.6	7.0
Palisades	7.3	7.0	7.1	6.9	7.3	7.1
JaMur	6.6	6.4	6.6	6.4	6.4	6.1
Geo	7.3	7.0	6.9	6.8	6.8	6.8
LSD	1.1	0.6	1.1	1.3	0.8	0.8
Cutivar	NS	***	NS	NS	**	**

2015 October Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.6	5.0	5.0	4.8	4.5	4.1
TifGrand	5.5	5.5	5.4	5.1	5.3	4.8
Celebration	5.5	5.5	5.1	4.8	5.0	4.4
Latitude 36	6.1	5.4	5.1	4.9	5.0	4.6
Zeon	6.0	5.9	5.6	5.9	5.6	5.4
Zorro	6.0	5.5	5.5	5.8	5.4	5.5
Palisades	6.5	5.9	5.9	5.6	5.5	5.4
JaMur	5.8	5.5	5.6	5.3	5.4	5.1
Geo	6.3	6.0	6.3	5.5	5.4	5.1
LSD	0.5	0.7	0.9	0.8	0.7	0.8
Cutivar	***	*	**	***	**	***
			Rough			
Tifway	5.6	5.5	5.4	5.3	5.0	4.8
TifGrand	5.6	5.4	5.5	5.5	5.4	5.3
Celebration	5.6	5.6	5.6	5.4	5.5	5.1
Latitude 36	5.8	5.4	5.5	5.3	5.4	5.1
Zeon	6.3	5.9	6.1	6.1	5.8	6.0
Zorro	6.3	6.1	6.0	6.0	5.8	5.8
Palisades	6.4	5.8	6.0	5.6	6.0	5.5
JaMur	6.0	5.8	5.8	5.8	5.8	5.6
Geo	6.0	6.0	6.1	6.0	6.9	5.5
LSD	0.7	0.6	0.6	0.7	0.5	0.5
Cutivar	*	*	***	**	***	***

2015 December Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.4	5.0	5.1	4.6	4.4	4.1
TifGrand	5.4	5.5	5.5	5.3	5.1	4.8
Celebration	5.3	5.5	5.3	5.1	5.1	5.0
Latitude 36	5.5	5.5	5.4	5.1	5.4	5.3
Zeon	5.6	5.9	5.5	5.3	5.3	5.4
Zorro	6.0	5.4	5.4	5.4	5.3	5.1
Palisades	6.0	5.9	5.9	5.4	5.3	5.0
JaMur	5.4	5.3	5.5	5.1	5.4	5.0
Geo	5.9	6.4	5.9	5.4	4.9	5.0
LSD	0.8	1.0	0.5	0.7	0.8	0.7
Cutivar	NS	*	**	NS	*	***
			Rough			
Tifway	4.1	5.3	5.3	4.6	4.9	4.8
TifGrand	4.1	5.9	5.5	5.4	5.1	5.0
Celebration	4.0	5.1	5.4	5.4	5.4	5.1
Latitude 36	4.4	5.1	5.5	5.4	5.4	5.5
Zeon	5.4	5.5	5.8	5.8	5.5	5.5
Zorro	5.8	5.6	5.6	5.5	5.5	5.4
Palisades	5.1	5.8	5.5	5.5	5.5	5.1
JaMur	5.3	5.5	5.6	5.4	5.6	5.5
Geo	5.5	5.8	5.5	5.6	5.5	5.0
LSD	0.7	0.8	0.4	0.7	0.6	0.6
Cutivar	***	*	NS	**	*	**

2016 February Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	3.1	4.6	4.9	4.3	3.4	3.1
TifGrand	3.1	5.3	5.4	4.5	4.4	4.0
Celebration	3.1	5.3	5.3	5.1	5.0	4.9
Latitude 36	3.3	5.4	5.4	5.4	5.4	5.0
Zeon	4.0	5.0	5.3	5.0	4.9	4.6
Zorro	4.0	4.9	5.1	5.0	4.8	4.6
Palisades	4.3	5.4	5.8	5.5	5.0	4.4
JaMur	3.5	4.5	5.1	4.8	4.8	4.3
Geo	3.3	5.5	6.3	5.4	4.6	4.5
LSD	0.6	1.2	1.0	1.0	1.0	0.9
Cutivar	***	NS	*	*	***	***
			Rough			
Tifway	3.0	4.3	4.4	4.1	4.1	3.9
TifGrand	3.0	4.1	4.5	4.6	4.4	4.6
Celebration	3.0	3.6	4.6	4.9	4.9	4.8
Latitude 36	3.0	3.6	4.3	5.0	4.9	5.0
Zeon	3.4	5.1	5.4	5.4	5.0	5.3
Zorro	3.4	5.4	5.5	5.3	5.3	5.0
Palisades	3.4	5.1	5.5	5.0	5.1	4.5
JaMur	3.4	4.9	5.1	5.1	5.3	4.9
Geo	4.3	5.0	5.5	5.5	5.5	4.5
LSD	0.7	1.1	0.6	0.8	0.9	0.7
Cutivar	***	***	***	**	**	***

2016 March Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.5	5.1	4.6	4.0	4.0	3.5
TifGrand	5.5	5.5	5.1	4.9	4.9	4.6
Celebration	5.6	5.6	5.3	4.4	4.5	4.1
Latitude 36	6.3	5.5	5.0	4.6	4.5	4.1
Zeon	5.6	6.0	5.6	5.6	5.5	5.0
Zorro	5.8	5.6	5.6	5.1	4.9	4.8
Palisades	5.9	6.4	5.6	5.3	4.8	4.3
JaMur	5.1	5.1	5.5	5.3	5.3	4.4
Geo	5.3	6.5	5.5	5.1	4.4	3.9
LSD	0.8	0.9	0.6	0.8	1.3	0.8
Cutivar	*	***	***	***	NS	***
			Rough			
Tifway	5.4	5.5	5.4	5.4	5.4	5.0
TifGrand	5.0	5.5	5.5	5.6	5.6	5.3
Celebration	5.1	5.9	5.8	5.6	5.6	5.5
Latitude 36	5.5	6.5	5.8	5.9	5.6	5.6
Zeon	5.4	6.0	6.0	6.0	5.8	5.8
Zorro	5.9	6.4	5.8	5.8	5.8	5.5
Palisades	5.3	5.8	5.6	5.5	5.6	5.3
JaMur	5.3	5.6	5.9	5.5	5.8	5.4
Geo	5.4	5.8	5.6	5.5	5.5	4.9
LSD	0.5	0.8	0.7	0.6	0.5	0.6
Cutivar	***	**	NS	NS	NS	**

2016 May Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.5	4.8	4.6	4.0	3.6	3.5
TifGrand	6.0	5.1	4.8	4.1	4.0	3.9
Celebration	5.8	4.0	4.4	3.9	3.8	3.8
Latitude 36	5.3	4.1	3.4	3.5	4.1	3.8
Zeon	7.0	6.0	6.0	5.0	4.4	3.8
Zorro	6.6	6.6	6.3	5.3	5.0	4.4
Palisades	6.3	5.3	5.1	4.4	4.1	3.4
JaMur	6.0	5.4	5.5	4.8	3.8	3.5
Geo	6.0	4.9	4.3	4.1	3.1	3.5
LSD	0.9	1.1	1.2	0.9	1.1	1.1
Cutivar	***	***	***	***	**	NS
			Rough			
Tifway	6.1	5.1	4.6	4.9	4.8	4.3
TifGrand	5.9	5.5	5.4	5.4	5.3	4.6
Celebration	6.1	5.5	5.4	5.5	5.5	5.4
Latitude 36	6.8	5.8	5.3	4.9	5.3	5.3
Zeon	6.6	6.8	6.5	6.5	5.3	5.9
Zorro	7.3	6.8	6.6	6.1	5.4	5.6
Palisades	6.5	6.3	6.0	5.8	5.3	5.0
JaMur	6.5	6.5	6.4	5.9	5.6	5.4
Geo	7.0	6.8	6.1	5.6	5.5	4.9
LSD	0.9	0.6	0.7	0.7	0.8	0.7
Cutivar	**	***	***	***	NS	***

2016 June Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.9	5.0	5.1	4.6	3.5	3.8
TifGrand	6.3	5.8	5.3	4.9	4.3	3.9
Celebration	5.6	5.8	4.9	4.9	4.1	3.8
Latitude 36	5.6	5.8	4.9	4.9	4.5	3.9
Zeon	7.5	6.0	5.6	5.0	3.9	3.8
Zorro	7.5	6.0	5.6	5.1	4.4	3.9
Palisades	6.6	6.0	5.5	5.1	4.4	3.9
JaMur	6.5	5.8	5.6	5.1	4.0	3.9
Geo	6.8	5.9	5.1	5.1	3.9	3.9
LSD	1.404	0.96	0.728	0.61	1.552	0.708
Cutivar	***	**	***	*	NS	NS
			Rough			
Tifway	5.6	5.5	5.4	5.0	5.3	4.6
TifGrand	5.9	5.5	5.5	5.1	5.3	5.0
Celebration	5.6	5.4	5.5	5.1	5.3	4.3
Latitude 36	5.9	5.3	5.3	4.9	5.4	5.3
Zeon	6.6	5.9	5.9	5.5	5.4	5.4
Zorro	7.0	6.0	5.6	5.5	5.5	5.3
Palisades	6.4	5.8	5.5	5.4	5.4	5.0
JaMur	6.3	5.9	5.5	5.6	5.5	5.3
Geo	6.3	5.9	5.5	5.5	5.3	4.6
LSD	1.1	0.6	0.5	0.5	0.5	0.7
Cutivar	*	**	*	***	NS	***

2016 July Turf Quality

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	5.5	5.5	5.4	4.4	3.9	3.0
	+TE	5.5	5.5	5.4	4.5	3.9	3.0
TifGrand	-TE	5.6	5.5	5.1	4.6	4.4	3.5
	+TE	5.6	5.6	5.5	5.1	4.5	3.5
Celebration	-TE	5.5	5.3	5.3	4.5	4.4	3.6
	+TE	5.5	5.4	5.3	4.5	4.5	3.6
Latitude 36	-TE	5.4	5.4	5.5	4.6	4.8	3.8
	+TE	5.4	5.4	5.6	4.9	4.8	3.8
Zeon	-TE	6.1	5.9	5.6	4.8	4.0	4.0
	+TE	6.1	6.1	5.9	5.3	4.1	4.0
Zorro	-TE	5.9	5.5	5.6	4.9	4.3	4.3
	+TE	5.9	5.9	6.1	5.4	4.5	4.3
Palisades	-TE	5.8	5.5	5.5	4.8	4.4	3.8
	+TE	5.8	5.9	6.0	5.3	4.4	3.8
JaMur	-TE	5.9	5.4	5.5	4.8	4.1	3.8
	+TE	5.9	5.9	6.3	5.3	4.1	3.8
Geo	-TE	6.3	5.4	5.6	5.0	4.1	3.6
	+TE	6.3	5.4	6.0	5.0	4.1	3.6
LSD		0.7	0.6	0.6	0.8	1.1	1.0
Cutivar		***	***	***	**	NS	**
Primo		NS	**	***	***	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		5.6	5.3	5.1	5.0	4.5	3.8
TifGrand		5.5	5.0	5.4	5.0	4.6	4.3
Celebration		5.6	5.1	5.5	5.3	4.8	3.6
Latitude 36		5.6	5.3	5.3	5.0	5.0	4.0
Zeon		5.9	5.8	5.8	5.4	4.5	4.4
Zorro		5.8	5.6	5.6	5.5	4.9	4.6
Palisades		5.9	5.8	5.5	5.4	4.6	4.4
JaMur		6.0	5.5	5.5	5.4	5.1	4.8
Geo		6.4	5.6	5.8	5.6	4.8	4.0
LSD		0.7	1.7	0.5	0.4	0.9	1.4
Cutivar		*	NS	**	***	NS	NS

2016 August Turf Quality

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	5.6	5.5	5.5	5.1	4.8	4.0
	+TE	5.5	5.8	5.6	5.1	4.8	4.1
TifGrand	-TE	5.8	5.3	5.6	5.0	5.0	4.1
	+TE	5.8	5.6	5.6	5.3	5.0	4.6
Celebration	-TE	5.5	5.8	5.4	4.9	5.1	4.1
	+TE	5.5	5.9	5.5	5.0	4.9	4.5
Latitude 36	-TE	5.5	5.5	5.4	5.1	5.0	4.0
	+TE	5.5	5.6	5.6	5.4	5.0	4.3
Zeon	-TE	5.9	5.8	5.5	5.1	5.1	4.5
	+TE	5.9	6.0	6.0	5.3	5.1	4.8
Zorro	-TE	5.5	5.8	5.6	5.4	5.4	4.6
	+TE	5.5	6.1	6.1	5.6	5.5	5.1
Palisades	-TE	5.5	5.8	5.8	5.1	5.1	4.6
	+TE	5.5	6.1	6.3	5.6	5.3	4.9
JaMur	-TE	5.4	5.5	5.8	5.4	5.3	4.8
	+TE	5.4	5.9	6.4	5.8	5.3	4.6
Geo	-TE	5.8	5.8	5.6	5.5	5.0	4.5
	+TE	5.8	6.1	6.0	5.8	5.1	4.8
LSD		0.9	0.8	0.8	0.8	0.9	1.0
Cutivar		NS	NS	*	**	NS	**
Primo		NS	**	***	**	NS	*
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		5.4	5.5	5.5	5.4	5.1	4.6
TifGrand		5.5	5.4	5.5	5.5	5.5	4.9
Celebration		5.5	5.5	5.5	5.5	5.4	4.4
Latitude 36		5.5	5.6	5.5	5.3	5.3	4.4
Zeon		5.8	5.8	5.6	5.5	5.3	4.9
Zorro		5.6	5.9	5.8	5.5	5.6	5.4
Palisades		5.3	5.5	5.5	5.5	5.5	5.0
JaMur		5.6	5.5	5.6	5.5	5.5	5.4
Geo		5.6	5.5	5.8	5.8	5.6	4.9
LSD		0.5	0.5	0.5	0.3	0.4	0.7
Cutivar		NS	NS	NS	*	*	**

2016 September Turf Quality

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	5.5	4.6	5.1	4.4	3.9	3.0
	+TE	5.5	5.0	5.3	4.5	4.0	3.0
TifGrand	-TE	5.5	5.3	5.1	4.8	4.1	3.1
	+TE	5.5	5.3	5.3	4.8	4.1	3.1
Celebration	-TE	5.8	5.4	5.4	4.4	4.3	3.0
	+TE	5.8	5.5	5.5	4.4	4.5	3.0
Latitude 36	-TE	5.8	5.4	5.4	4.5	4.6	3.1
	+TE	5.8	5.5	5.4	4.8	4.8	3.1
Zeon	-TE	5.9	5.5	5.3	4.8	4.4	3.9
	+TE	6.0	5.6	5.4	5.0	4.5	4.3
Zorro	-TE	5.9	5.3	5.4	5.1	4.6	4.4
	+TE	6.0	5.4	5.6	5.6	4.9	4.5
Palisades	-TE	5.8	5.4	5.5	4.9	4.4	3.8
	+TE	5.8	5.8	5.6	5.5	4.6	4.0
JaMur	-TE	5.9	5.1	5.4	4.8	4.6	4.1
	+TE	5.9	5.6	5.8	5.1	4.9	4.3
Geo	-TE	5.9	5.5	5.6	5.5	4.5	4.3
	+TE	5.9	5.9	6.0	5.9	4.8	4.3
LSD		0.6	0.6	0.5	0.9	0.9	0.5
Cutivar		*	***	***	***	**	***
Primo		NS	**	**	**	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		5.8	5.5	5.5	4.9	4.5	3.6
TifGrand		5.8	5.4	5.4	5.0	4.6	3.9
Celebration		5.9	5.5	5.5	5.5	5.0	3.4
Latitude 36		5.8	5.5	5.5	5.1	5.0	3.8
Zeon		6.1	5.8	5.6	5.8	4.9	4.6
Zorro		6.0	5.9	5.6	5.5	5.5	4.8
Palisades		5.8	6.0	6.1	5.8	5.0	4.9
JaMur		6.1	5.8	5.6	5.5	5.5	5.1
Geo		5.9	6.1	5.9	5.6	5.3	4.6
LSD		0.8	0.4	0.5	0.7	1.0	0.9
Cutivar		NS	***	**	**	NS	***

2016 October Turf Quality

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	6.1	5.0	4.9	4.0	3.0	3.0
	+TE	6.1	5.3	5.0	4.0	3.1	3.0
TifGrand	-TE	6.6	6.1	5.4	4.6	3.5	3.0
	+TE	6.6	6.5	5.6	4.9	3.9	3.0
Celebration	-TE	6.8	5.6	5.3	4.0	3.6	3.0
	+TE	6.8	5.9	5.5	4.5	4.1	3.0
Latitude 36	-TE	7.0	5.9	5.4	4.1	4.3	3.0
	+TE	7.0	6.1	5.6	4.4	4.4	3.0
Zeon	-TE	7.1	6.1	5.3	4.9	4.0	3.5
	+TE	7.1	6.6	6.0	5.3	4.4	4.0
Zorro	-TE	6.9	5.9	4.8	5.1	4.9	3.8
	+TE	6.9	6.3	6.4	5.9	5.1	4.3
Palisades	-TE	7.1	6.0	5.8	4.8	4.4	3.4
	+TE	7.1	6.5	6.3	5.6	4.8	3.4
JaMur	-TE	7.3	5.8	5.5	4.8	4.3	3.4
	+TE	7.3	6.5	6.0	5.5	5.0	3.9
Geo	-TE	7.3	6.3	6.0	5.3	4.5	3.8
	+TE	7.3	6.8	6.6	5.9	4.9	4.4
LSD		1.0	0.9	0.8	1.3	1.3	1.0
Cutivar		***	***	***	***	***	***
Primo		NS	***	***	**	*	*
Cutivar*Primo		NS	NS	*	NS	NS	NS
				Rough			
Tifway		6.5	5.6	5.5	4.8	4.1	3.3
TifGrand		6.9	6.0	5.6	5.3	4.4	3.3
Celebration		7.1	6.3	5.9	5.3	4.9	3.1
Latitude 36		7.1	6.3	5.9	4.8	4.9	3.3
Zeon		7.4	7.0	6.4	5.8	5.0	4.5
Zorro		7.1	7.3	6.3	5.4	5.3	4.5
Palisades		7.4	7.1	6.4	5.6	5.3	4.6
JaMur		7.5	7.0	6.1	5.4	5.4	5.0
Geo		7.0	6.3	5.5	5.3	5.1	4.0
LSD		1.1	0.8	0.7	0.7	1.2	0.7
Cutivar		NS	***	***	**	NS	***

2016 November Turf Quality

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	5.4	5.1	4.8	4.3	3.8	3.0
TifGrand	5.6	5.3	5.0	4.6	3.9	3.0
Celebration	5.4	5.1	5.0	4.5	4.0	3.0
Latitude 36	5.8	5.3	5.0	4.6	4.5	3.0
Zeon	5.9	5.6	5.4	5.0	4.9	4.0
Zorro	5.5	5.8	5.4	5.3	4.6	4.0
Palisades	6.0	5.6	5.9	5.0	4.9	3.6
JaMur	5.9	5.9	5.4	5.3	4.6	4.0
Geo	5.6	5.9	5.8	5.5	4.5	3.9
LSD	0.7	0.7	0.5	0.8	1.3	0.8
Cutivar	NS	**	***	**	NS	***
			Rough			
Tifway	4.9	5.0	4.9	4.5	4.4	3.4
TifGrand	5.1	5.1	5.0	4.8	4.4	3.6
Celebration	4.8	5.1	5.1	4.6	4.6	3.4
Latitude 36	4.9	5.1	5.0	4.5	4.6	3.3
Zeon	5.9	5.8	5.8	5.3	4.9	4.0
Zorro	5.8	6.0	5.4	5.0	4.9	4.3
Palisades	6.0	5.8	5.3	5.1	5.0	4.4
JaMur	5.8	5.9	5.4	5.0	5.0	4.5
Geo	6.0	5.6	5.5	5.4	4.8	4.0
LSD	1.0	0.6	0.5	0.6	0.6	0.8
Cutivar	***	***	***	**	*	***

2016 May NDVI

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	0.69	0.52	0.48	0.42	0.44	0.37
TifGrand	0.69	0.50	0.46	0.42	0.42	0.43
Celebration	0.64	0.38	0.41	0.35	0.37	0.40
Latitude 36	0.54	0.35	0.37	0.42	0.45	0.41
Zeon	0.70	0.64	0.67	0.51	0.43	0.35
Zorro	0.71	0.72	0.66	0.58	0.52	0.44
Palisades	0.68	0.53	0.53	0.42	0.40	0.38
JaMur	0.65	0.60	0.54	0.50	0.40	0.36
Geo	0.67	0.46	0.42	0.40	0.37	0.33
LSD	0.13	0.11	0.18	0.14	0.13	0.13
Cutivar	*	***	***	**	*	NS
			Rough			
Tifway	0.68	0.50	0.43	0.51	0.50	0.40
TifGrand	0.69	0.67	0.54	0.54	0.51	0.45
Celebration	0.67	0.52	0.49	0.56	0.57	0.51
Latitude 36	0.71	0.56	0.53	0.41	0.49	0.48
Zeon	0.68	0.70	0.68	0.69	0.54	0.62
Zorro	0.70	0.69	0.69	0.67	0.62	0.64
Palisades	0.68	0.62	0.65	0.60	0.51	0.52
JaMur	0.65	0.64	0.65	0.64	0.58	0.60
Geo	0.66	0.67	0.66	0.62	0.57	0.45
LSD	0.09	0.20	0.11	0.11	0.13	0.14
Cutivar	NS	*	***	***	NS	***

2016 June NDVI

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	0.64	0.50	0.63	0.52	0.30	0.33
	+TE	0.64	0.50	0.63	0.52	0.29	0.33
TifGrand	-TE	0.67	0.69	0.56	0.47	0.37	0.40
	+TE	0.67	0.68	0.56	0.47	0.36	0.39
Celebration	-TE	0.58	0.55	0.53	0.52	0.28	0.32
	+TE	0.58	0.55	0.54	0.53	0.29	0.32
Latitude 36	-TE	0.58	0.60	0.55	0.53	0.41	0.38
	+TE	0.58	0.59	0.56	0.52	0.41	0.38
Zeon	-TE	0.66	0.66	0.59	0.50	0.31	0.35
	+TE	0.66	0.66	0.59	0.50	0.31	0.36
Zorro	-TE	0.65	0.68	0.65	0.46	0.36	0.37
	+TE	0.65	0.68	0.65	0.48	0.36	0.37
Palisades	-TE	0.65	0.64	0.61	0.56	0.37	0.31
	+TE	0.65	0.65	0.60	0.56	0.38	0.32
JaMur	-TE	0.66	0.67	0.65	0.55	0.32	0.40
	+TE	0.66	0.67	0.65	0.55	0.32	0.39
Geo	-TE	0.66	0.58	0.53	0.50	0.31	0.34
	+TE	0.66	0.59	0.53	0.50	0.32	0.34
LSD		0.13	0.14	0.12	0.19	0.31	0.12
Cutivar		***	***	***	NS	NS	*
Primo		NS	NS	NS	NS	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		0.62	0.62	0.58	0.47	0.44	0.36
TifGrand		0.61	0.6.0	0.60	0.53	0.51	0.36
Celebration		0.66	0.57	0.63	0.54	0.50	0.32
Latitude 36		0.67	0.57	0.54	0.53	0.58	0.46
Zeon		0.65	0.64	0.63	0.59	0.51	0.39
Zorro		0.61	0.6	0.64	0.55	0.56	0.43
Palisades		0.65	0.59	0.61	0.56	0.59	0.45
JaMur		0.61	0.63	0.63	0.61	0.61	0.47
Geo		0.63	0.64	0.66	0.59	0.53	0.41
LSD		0.1	0.14	0.12	0.13	0.16	0.19
Cutivar		NS	NS	NS	NS	NS	NS

2016 July NDVI

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	0.63	0.59	0.54	0.51	0.41	0.34
	+TE	0.63	0.62	0.58	0.56	0.42	0.34
TifGrand	-TE	0.71	0.63	0.63	0.55	0.50	0.33
	+TE	0.71	0.73	0.71	0.63	0.50	0.33
Celebration	-TE	0.60	0.50	0.53	0.50	0.47	0.33
	+TE	0.61	0.55	0.61	0.48	0.48	0.34
Latitude 36	-TE	0.57	0.52	0.58	0.49	0.48	0.34
	+TE	0.57	0.55	0.66	0.54	0.55	0.33
Zeon	-TE	0.63	0.59	0.50	0.55	0.47	0.44
	+TE	0.63	0.61	0.62	0.62	0.48	0.43
Zorro	-TE	0.61	0.60	0.53	0.52	0.51	0.47
	+TE	0.58	0.66	0.65	0.66	0.57	0.49
Palisades	-TE	0.56	0.61	0.60	0.56	0.45	0.39
	+TE	0.57	0.67	0.65	0.68	0.48	0.39
JaMur	-TE	0.60	0.55	0.59	0.53	0.52	0.44
	+TE	0.59	0.68	0.67	0.64	0.54	0.44
Geo	-TE	0.64	0.54	0.59	0.53	0.44	0.37
	+TE	0.64	0.61	0.64	0.57	0.44	0.41
LSD		0.15	0.15	0.14	0.13	0.22	0.21
Cutivar		**	***	*	**	NS	*
Primo		NS	***	***	***	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		0.56	0.57	0.52	0.53	0.55	0.40
TifGrand		0.67	0.66	0.70	0.54	0.52	0.44
Celebration		0.62	0.55	0.60	0.49	0.52	0.30
Latitude 36		0.65	0.55	0.55	0.42	0.44	0.35
Zeon		0.62	0.64	0.59	0.45	0.55	0.37
Zorro		0.57	0.62	0.63	0.55	0.56	0.45
Palisades		0.60	0.64	0.65	0.58	0.52	0.45
JaMur		0.58	0.66	0.62	0.57	0.59	0.53
Geo		0.62	0.61	0.58	0.60	0.58	0.44
LSD		0.11	0.16	0.13	0.11	0.20	0.17
Cutivar		NS	NS	**	***	NS	*

2016 August NDVI

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	0.48	0.54	0.51	0.55	0.42	0.37
	+TE	0.49	0.61	0.54	0.56	0.43	0.37
TifGrand	-TE	0.60	0.55	0.57	0.53	0.48	0.36
	+TE	0.60	0.59	0.66	0.59	0.55	0.40
Celebration	-TE	0.56	0.50	0.52	0.49	0.50	0.32
	+TE	0.58	0.55	0.56	0.54	0.52	0.32
Latitude 36	-TE	0.54	0.50	0.57	0.49	0.47	0.34
	+TE	0.54	0.52	0.61	0.63	0.54	0.37
Zeon	-TE	0.57	0.46	0.51	0.48	0.51	0.42
	+TE	0.57	0.53	0.56	0.59	0.57	0.44
Zorro	-TE	0.49	0.53	0.47	0.57	0.57	0.39
	+TE	0.49	0.61	0.62	0.62	0.63	0.51
Palisades	-TE	0.50	0.51	0.56	0.52	0.39	0.36
	+TE	0.50	0.64	0.62	0.61	0.50	0.37
JaMur	-TE	0.61	0.51	0.51	0.54	0.48	0.44
	+TE	0.61	0.56	0.63	0.63	0.53	0.44
Geo	-TE	0.58	0.55	0.56	0.52	0.53	0.41
	+TE	0.58	0.63	0.66	0.66	0.55	0.42
LSD		0.25	0.15	0.15	0.14	0.18	0.18
Cutivar		NS	NS	NS	NS	**	*
Primo		NS	***	***	***	**	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		0.56	0.50	0.50	0.500	0.51	0.43
TifGrand		0.61	0.54	0.55	0.44	0.48	0.39
Celebration		0.59	0.48	0.54	0.47	0.44	0.37
Latitude 36		0.52	0.47	0.45	0.44	0.48	0.35
Zeon		0.55	0.55	0.53	0.43	0.52	0.44
Zorro		0.49	0.59	0.61	0.53	0.58	0.55
Palisades		0.44	0.58	0.56	0.53	0.56	0.53
JaMur		0.51	0.49	0.58	0.54	0.55	0.57
Geo		0.50	0.57	0.55	0.58	0.58	0.4
LSD		0.12	0.13	0.14	0.12	0.13	0.13
Cutivar		**	*	NS	**	*	***

2016 September NDVI

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	0.47	0.49	0.41	0.39	0.28	0.31
	+TE	0.48	0.52	0.39	0.42	0.29	0.31
TifGrand	-TE	0.55	0.59	0.47	0.44	0.35	0.31
	+TE	0.48	0.60	0.48	0.49	0.38	0.32
Celebration	-TE	0.64	0.55	0.58	0.43	0.40	0.33
	+TE	0.64	0.57	0.56	0.47	0.41	0.36
Latitude 36	-TE	0.57	0.50	0.52	0.46	0.37	0.29
	+TE	0.60	0.55	0.54	0.52	0.39	0.30
Zeon	-TE	0.54	0.52	0.50	0.49	0.47	0.42
	+TE	0.57	0.57	0.54	0.53	0.47	0.42
Zorro	-TE	0.58	0.55	0.51	0.58	0.46	0.43
	+TE	0.59	0.56	0.58	0.60	0.51	0.43
Palisades	-TE	0.61	0.57	0.54	0.51	0.47	0.40
	+TE	0.62	0.58	0.58	0.57	0.52	0.40
JaMur	-TE	0.61	0.50	0.53	0.51	0.48	0.46
	+TE	0.61	0.60	0.57	0.58	0.55	0.46
Geo	-TE	0.64	0.54	0.59	0.50	0.40	0.45
	+TE	0.66	0.60	0.61	0.58	0.44	0.46
LSD		0.10	0.15	0.10	0.13	0.20	0.18
Cutivar		***	NS	***	***	***	***
Primo		NS	*	*	***	NS	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		0.58	0.58	0.52	0.43	0.43	0.32
TifGrand		0.70	0.63	0.65	0.52	0.43	0.32
Celebration		0.64	0.65	0.66	0.62	0.51	0.37
Latitude 36		0.61	0.63	0.68	0.49	0.46	0.37
Zeon		0.60	0.60	0.56	0.56	0.49	0.43
Zorro		0.59	0.64	0.61	0.58	0.57	0.47
Palisades		0.63	0.65	0.61	0.60	0.58	0.51
JaMur		0.58	0.60	0.60	0.59	0.57	0.45
Geo		0.62	0.63	0.63	0.58	0.59	0.42
LSD		0.11	0.09	0.10	0.12	0.18	0.23
Cutivar		*	NS	**	***	*	NS

2016 October NDVI

		Full Sun	30%	50%	70%	80%	90%
				Fairway			
Tifway	-TE	0.65	0.53	0.53	0.42	0.26	0.30
	+TE	0.65	0.59	0.54	0.42	0.32	0.30
TifGrand	-TE	0.71	0.64	0.58	0.48	0.34	0.31
	+TE	0.71	0.69	0.63	0.55	0.39	0.31
Celebration	-TE	0.70	0.53	0.55	0.45	0.35	0.28
	+TE	0.70	0.64	0.61	0.52	0.40	0.28
Latitude 36	-TE	0.69	0.57	0.58	0.45	0.42	0.27
	+TE	0.68	0.61	0.62	0.51	0.50	0.27
Zeon	-TE	0.67	0.59	0.57	0.49	0.46	0.42
	+TE	0.66	0.63	0.61	0.58	0.50	0.45
Zorro	-TE	0.65	0.64	0.53	0.57	0.48	0.44
	+TE	0.66	0.66	0.62	0.64	0.53	0.46
Palisades	-TE	0.66	0.60	0.58	0.56	0.48	0.34
	+TE	0.66	0.63	0.63	0.58	0.53	0.39
JaMur	-TE	0.68	0.62	0.60	0.54	0.50	0.44
	+TE	0.68	0.65	0.63	0.59	0.57	0.46
Geo	-TE	0.68	0.61	0.61	0.57	0.44	0.40
	+TE	0.68	0.66	0.70	0.64	0.51	0.44
LSD		0.08	0.08	0.09	0.11	0.24	0.17
Cutivar		*	***	***	***	***	***
Primo		NS	***	***	***	*	NS
Cutivar*Primo		NS	NS	NS	NS	NS	NS
				Rough			
Tifway		0.66	0.57	0.55	0.44	0.41	0.31
TifGrand		0.70	0.67	0.60	0.42	0.49	0.35
Celebration		0.69	0.64	0.60	0.55	0.50	0.34
Latitude 36		0.71	0.67	0.62	0.53	0.49	0.43
Zeon		0.67	0.63	0.64	0.61	0.56	0.50
Zorro		0.66	0.66	0.66	0.61	0.59	0.51
Palisades		0.67	0.65	0.65	0.62	0.58	0.53
JaMur		0.67	0.64	0.64	0.60	0.59	0.56
Geo		0.63	0.62	0.60	0.60	0.58	0.46
LSD		0.07	0.07	0.08	0.09	0.14	0.13
Cutivar		*	**	*	***	**	***

2016 November NDVI

	Full Sun	30%	50%	70%	80%	90%
			Fairway			
Tifway	0.60	0.54	0.56	0.43	0.33	0.21
TifGrand	0.67	0.62	0.56	0.46	0.32	0.23
Celebration	0.61	0.57	0.63	0.46	0.42	0.23
Latitude 36	0.64	0.57	0.61	0.47	0.44	0.24
Zeon	0.62	0.66	0.65	0.52	0.42	0.33
Zorro	0.63	0.65	0.64	0.60	0.47	0.41
Palisades	0.64	0.64	0.65	0.55	0.50	0.31
JaMur	0.63	0.61	0.62	0.60	0.49	0.39
Geo	0.62	0.64	0.67	0.61	0.46	0.41
LSD	0.07	0.07	0.09	0.12	0.22	0.16
Cutivar	NS	***	**	***	NS	***
			Rough			
Tifway	0.55	0.54	0.51	0.43	0.41	0.29
TifGrand	0.60	0.63	0.56	0.52	0.44	0.38
Celebration	0.58	0.58	0.60	0.57	0.53	0.27
Latitude 36	0.53	0.59	0.57	0.51	0.51	0.29
Zeon	0.64	0.61	0.63	0.57	0.49	0.45
Zorro	0.60	0.65	0.62	0.55	0.55	0.48
Palisades	0.65	0.66	0.65	0.57	0.57	0.51
JaMur	0.64	0.65	0.65	0.55	0.55	0.50
Geo	0.66	0.68	0.65	0.61	0.52	0.42
LSD	0.09	0.08	0.11	0.09	0.12	0.13
Cutivar	***	***	**	***	**	***